JOURNAL OF THE A·I·E·E·

MAY 1928

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PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

MEETINGS

of the

American Institute of Electrical Engineers

NEW HAVEN REGIONAL MEETING, Northeastern District No. 1 (May 9-12, 1928)

SUMMER CONVENTION, Denver, Colo. (June 25-29, 1928)

PACIFIC COAST CONVENTION, Spokane, Washington (August 28-31, 1928)

ATLANTA REGIONAL MEETING, Southern District No. 4 (October 29-31, 1928)

For Future Section Meetings, see notices in this issue

MEETINGS OF OTHER SOCIETIES

National Electric Light Association
Middle West Division, St. Louis, Mo., May 9-11, 1928

American Society of Mechanical Engineers, Pittsburgh, Pa., May 14-17, 1928

Illuminating Engineers and New York Section A. I. E. E., Engineering Societies Bldg., New York, N. Y., May 18, 1928

Institute of Radio Engineers, Engineering Societies Bldg., New York, N. Y., June 6, 1928

National Electric Light Association, Atlantic City, June 4-8, 1928
Pacific Coast Division, Hotel Huntington, Pasadena, Calif., June 12-15, 1928
Northwest Division, Portland, Oregon, June 19-22, 1928

JOURNAL

OF THE

American Institute of Electrical Engineers

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33 West 39th Street, New York

PUBLICATION COMMITTEE

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Changes of advertising copy should reach Institute headquarters by the 15th day of the month for the issue of the following month.
Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Philippines, $10.50 to Canada and $11.00 to all other countries. Single copies $1.00.
Entered as matter of the second class at the Post Office, New York, N. Y., May 10, 1905, under the Act of Congress, March 3, 1879.
Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized on August 3, 1918.

Vol. XLVII — MAY 1928 — Number 5

TABLE OF CONTENTS

Papers, Discussions, Reports, Etc.

Institute and Related Activities

A REQUEST FOR CHANGE OF ADDRESS must be received at Institute headquarters at least ten days before the date of issue with which it is to take effect. Duplicate copies cannot be sent without charge to replace those issues undelivered through failure to send such advance notice. With your new address be sure to mention the old one, indicating also any changes in business connections.

(The Journal of the A. I. E. E. is indexed in Industrial Arts Index.)

Current Electrical Articles Published by Other Societies

Bell Laboratories Record, March 1928

New Devices in Television

Institute of Radio Engineers, Proceedings, April 1928

The International Radiotelegraph Conference of Washington, 1927, by W. D. Terrell

Modes of Vibration in Piezo-Electric Crystals, by A. Crossley

Some Characteristics and Applications of Four-Electrode Tubes, by J. C. Warner

The Inverted Vacuum Tube, a Voltage Reproducing Power Amplifier, by Frederick Emmons Terman

Development of a New Power Amplifier Tube, by C. R. Hanna, L. Sutherlin and C. B. Upp

Measurements of Vacuum-Tube Capacities by a Transformer Balance, by Harold A. Wheeler

A Direct-Capacity Bridge for Vacuum-Tube Measurements, by Lincoln Walsh

A Bridge Method for the Measurement of Inter-Electrode Admittance in Vacuum Tubes, by E. T. Hoch

Broadcast Control Operation, by Carl Dreher

Review of Current Literature, by Stuart Ballantine

Bibliography on Piezo-Electricity, by W. G. Cady

Iron & Steel Engineer, March 1928

Electrical Distributing System and Equipment of the National Tube Co., Gary, Ind., by E. L. Upp

JOURNAL OF THE A. I. E. E.

DEVOTED TO THE ADVANCEMENT OF THE THEORY AND PRACTISE OF ELECTRICAL ENGINEERING AND THE ALLIED ARTS AND SCIENCES

The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

Vol. XLVII | MAY, 1928 | Number 5

Future National and Regional Institute Meetings

On account of the constant expansion of Institute activities, it has become increasingly evident that all National and Regional meetings should be carefully coordinated. With this object in view, all applications for meetings are now referred to the Committee on Coordination of Institute Activities before a schedule for a year is adopted.

The Coordination Committee has had under consideration for some months the schedule for the calendar year 1929 and on April 3 held a meeting and adopted the following report embodying recommendations to the Board of Directors.

To the Members of the
Board of Directors A. I. E. E.

Gentlemen:

One of the duties of this Committee is to make recommendations to the Board of Directors regarding the dates and places of future National and Regional conventions. It is obvious that these National and Regional conventions should be carefully coordinated, and hence all applications for such meetings should be received far in advance of proposed meeting dates, so that a complete schedule for a year may be recommended at one time, after considering conflicting requests, financial obligations involved, meetings already announced by other societies, the work of the various committees concerned: for example, the Meetings and Papers, Publications, Finance, Sections, and other committees, all with the object of obtaining the best distribution of our meetings, both geographically and chronologically.

On March 1, 1928, this Committee communicated with the officers of the ten Geographical Districts and the fifty-two Sections, explaining in detail the necessity for early action and requesting that applications for National or Regional meetings to be held during the year 1929, be received by the Committee not later than April 1.

In deciding upon the recommendations to be made regarding dates and locations of future meetings, this Committee has voted to observe as far as practicable the following general principles:

1. A complete schedule of National and Regional meetings for an entire calendar year should be decided upon at one time, so that the meetings shall be properly coordinated and distributed both geographically and chronologically.

2. That the dates of all National and Regional conventions should be arranged so that there will be an interval of at least six weeks between any two of these meetings.

3. That rotation of the Annual Summer Convention from one part of the country to another, year by year, is desirable.

4. Experience with Regional meetings indicates clearly that they constitute one of the most important and valuable activities of the Institute, and they should be continued and encouraged.

5. That not more than one meeting be held in any one Geographical District in one calendar year, unless there are not enough applications from other Districts to make up as complete a schedule for the year as appears to be desirable, in which case two meetings within one District may be recommended.

In response to the Committee's letter of March 1, 1928, applications for meetings have been received from several of the District and Section officers. The Committee, after careful consideration of the various elements involved, recommends the adoption of the following schedule of meetings to be held during 1929, which provides for the usual three National Conventions and all the Regional meetings for which requests have been received:

Winter Convention, New York, N. Y., District No. 3 during week beginning Monday, January 28.

Regional Meeting, Cincinnati, Ohio, District No. 2, March.

Regional Meeting, District 7 or 5, South West or Great Lakes between May 1 and May 15.
(place and exact dates to be decided by District officers).

Summer Convention, Swampscott, Mass., District No. 1, June 24-28.

Pacific Coast Convention, California, Districts 8-9, late Summer.
(place and exact dates to be decided by the officers of Districts 8 and 9)

Participation in World Engineering Congress, Tokio, Japan, October.

Regional Meeting, District 5 or 7, Great Lakes or South West, November.
(place and exact dates to be decided by District officers).

As it is important that our meeting dates be given wide publicity and that the necessary hotel and other facilities be reserved promptly, also that the dates be communicated by letter to the secretaries of numerous engineering and allied societies, with a view to avoiding

conflicts, we unanimously recommend that this schedule be definitely adopted at the meeting of the Directors on April 6.

Very truly yours,

COMMITTEE ON COORDINATION OF INSTITUTE ACTIVITIES

C. O. BICKELHAUPT
(Chairman Law Com.)

H. P. CHARLESWORTH
(Chairman Meetings and Papers Com.)

F. L. HUTCHINSON
(National Secretary)

H. A. KIDDER
(Chairman, Finance Com.)

W. B. KOUWENHOVEN
(Chairman, Sections Com.)

E. B. MEYER
(Chairman, Publication Com.)

G. L. KNIGHT, *Chairman*

The above report was unanimously approved by the Board of Directors, and the list of Institute meetings has been communicated to the secretaries of the principal engineering and allied societies with a view to the elimination of conflicting dates as far as may be feasible.

Some Leaders of the A. I. E. E.

Charles Schenck Bradley, Manager of the Institute (1894-7) (1899-1902) and Vice-President (1897-9) was born in Victoria, Canada, April 12, 1853. He is, however, a descendent of six generations of New England stock and inherits the ingenuity typical of his Yankee ancestry. After taking a special course at Rochester University, he was impressed by the reading of books by Tyndall, the great English physicist with the possibility of applying heat and electricity to the work of the world, and in 1881 came to New York to associate himself with Thomas A. Edison. For several years, successively with his own experimental laboratory at Yonkers, N. Y., he worked in the field of electrical illumination, then in its infancy. Ninety devices for the transmission of power over long distances were the outgrowth of his invention genious. A method of multipolar windings was also originated by him, as was a rotary converter to assist in the economical distribution of current to street car systems, illuminating stations and power plants. Although Mr. Bradley has done much as a physicist, his chief work has been along chemical lines. He was one of these to assist in the process of changing aluminum from a semi-precious to a basic metal, reducing the price over 10 per cent. His company affiliations from time to time were with the Fort Wayne Co., (1882-92); Thomson-Houston Co. (1892-96); the Ampere Electro-Chemical Co. (1896-1904); General Electric Company (1904-06); Bradley Copper Process Company (1906-13); Chemical Research, N. Y. (1913-14) and the U. S. Reduction Co. (1916-1925). His invention for the fixation of nitrogen was at the time, an epochmaking achievement. His maxim was that the only way to achieve was to "go ahead and do things" and to this slogan he clung in all undertakings. Fifty patents were granted him for various processes for the economical extraction of copper by electrolytic means, and to him is attributed the design of a rotary furnace for the production of carbide of calcium. In his ambition to accomplish, Mr. Bradley lamented the fact that most of the information he was able to obtain from consulting experts was given in negative form, instructing how not to do things rather than just what to do. Conservation of both time and power was to him ultra important. His contention was that extravagance was far more often responsible for failure than actual inability to achieve. A full realization and application of resources, he believes, cannot fail to produce gratifying success. Mr. Bradley is a member of the Genessee Valley Club and the Chemists' Club of New York.

Notice of Annual Meeting of Institute

The Annual Meeting of the American Institute of Electrical Engineers will be held in Denver, Colorado, on Tuesday morning, June 26, 1928. This will constitute one session of the Annual Summer Convention which is to be held in Denver, June 25-29.

At this meeting the annual report of the Board of Directors, also the reports of the Committee of Tellers on the ballots cast for the election of officers, and upon the proposed Constitutional Amendments, will be presented.

Such other business, if any, as may properly come before an annual business meeting will be considered.

This Annual Meeting is to be held for the first time during the Summer Convention in accordance with a vote of the membership at a Special Meeting held in Chicago last year.

F. L. HUTCHINSON,
National Secretary.

Waldemar Kaempffert, science and engineering editor of the New York *Times*, has been appointed director of the Chicago Industrial Museum. He will pass several months studying similar museums in Paris, London, Vienna and Munich before taking up his new work. The Chicago Industrial Museum, which will have 400,000 sq. ft. of floor area has been made possible by a gift of $3,000,000 from Julius Rosenwald in addition to $5,000,000 appropriated by the South Park Commissioners to reconstruct for this use the fine arts building of the World's Fair of 1893. Mr. Kaempffert emphasizes the intention to make the museum more than a heterogeneous collection of machines. It is to be an educational institution for the presentation of scientific and engineering principles.

Abridgment of

Tuned Radio-Frequency Amplifiers

BY R. S. GLASGOW[1]

Associate, A. I. E. E.

Synopsis.—A simplified method of calculating the performance of a tuned amplifier circuit is given and the effect of the various circuit constants on the characteristics is shown. The predicted results are found to check experimental observation quite closely. Curves showing the performance obtained with various types of tubes are also given. The factors affecting the stability are pointed out and typical methods for suppressing undesired oscillations are given, together with the principles involved.

IN Fig. 1 is shown a transformer having an impedance Z_1 in series with the primary, and an impedance Z_2 connected across the secondary. These impedances may be resistance, inductance, capacity, or any combination thereof. The impedance of the primary winding with the secondary on open circuit is Z_p, and that of the secondary with the primary open is Z_s. The mutual

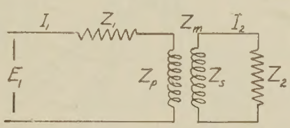

FIG. 1

impedance between primary and secondary is Z_m, the vector expression for which is $j\ \omega\ M$ in the case of an air-core transformer, where M is the mutual inductance and ω is $2\ \pi$ times the frequency of the applied voltage.

Applying Kirchoff laws we have:

$$E_1 = I_1 Z_1 + I_1 Z_p + I_2 Z_m \qquad (1)$$

$$O = I_2 Z_s + I_2 Z_2 + I_1 Z_m \qquad (2)$$

Combining (1) and (2), we obtain,

$$I_1 = \frac{E_1 (Z_2 + Z_s)}{(Z_1 + Z_p)(Z_2 + Z_s) - Z_m^2} \qquad (3)$$

and

$$I_2 = \frac{-E_1 Z_m}{(Z_1 + Z_p)(Z_2 + Z_s) - Z_m^2} \qquad (4)$$

which give us the vector expressions for the respective primary and secondary currents in any type of transformer in terms of the impedance in the circuit.

In Fig. 2a is shown a single stage of the ordinary type of tuned amplifier and in Fig. 2b, the electrical equivalent of the circuit.

The current in the secondary from equation (4) is

$$I_2 = \frac{\mu E_g \,.\, j\ \omega\ M}{(r_p + R_1 + j\ \omega\ L_1)\left(R_2 + j\ \omega\ L_2 - j\ \dfrac{1}{\omega\ C_2}\right) + \omega^2 M^2} \qquad (5)$$

If a small number of turns are used on the primary, its impedance $R_1 + j\ \omega\ L_1$ can ordinarily be neglected in comparison with r_p which is of the order of 10,000 to 20,000 ohms, depending on the type of tube used. At resonance $\omega\ L_2 = \dfrac{1}{\omega\ C_2}$ and the impedance of the entire secondary circuit is merely R_2, so that the maximum magnitude of the secondary current to a sufficiently close degree of approximation becomes

$$I_2 = \frac{\mu\ E_g\ \omega\ M}{r_p\ R_2 + \omega^2\ M^2} \qquad (6)$$

The voltage across the secondary is

$$E = I_2\ \omega\ L_2 = \frac{\mu\ E_g\ \omega\ M}{r_p\ R_2 + \omega^2\ M^2}\ \omega\ L_2 \qquad (7)$$

Defining the voltage amplification per stage K as the ratio of the output voltage to the input voltage applied to grid, we have

$$K = \frac{E}{E_g} = \frac{\mu\ \omega\ M}{r_p\ R^2 + \omega^2\ M^2}\ \omega\ L_2 \qquad (8)$$

If the mutual inductance in equation (8) is considered to be the variable, the voltage amplification can be shown to be maximum when $\omega^2 M^2 = r_p R_2$ (9)

Substituting this value of optimum mutual inductance in equation (8), we obtain

$$K_{max} = \frac{1}{2}\ \frac{\mu}{\sqrt{r_p}}\ \frac{\omega\ L_2}{\sqrt{R_2}} \qquad (10)$$

Equation (10) gives an expression for the maximum possible amplification that can be obtained with a

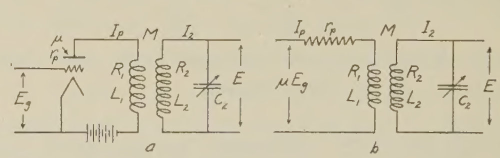

FIG. 2

given tube and a fixed value of secondary inductance. It is interesting to note that when optimum coupling is employed, the amplification is directly proportional to the ratio of the reactance of the coil to the square root of its resistance. Also, from the viewpoint of voltage amplification alone, the best type of tube to use is one which has the largest ratio of μ to $\sqrt{r_p}$. If the coupling used is less than the optimum value as given by equation (9), the effect of tube and coil resistance becomes greater,

1. Associate Professor of Electrical Engineering, Washington University, St. Louis, Mo.

Presented at the A. I. E. E. Regional Meeting, St. Louis, Mo., March 7-9, 1928. Complete copies upon request.

lying somewhere between the square root and the first power of the resistance. It is interesting to note that the turns ratio between primary and secondary does not enter into the expression for the amplification, the the mutual inductance between them being the criterion. Thus a primary coil of a few turns, closely coupled to the secondary, will produce the same result as a coil of a greater number of turns more loosely coupled.

The data in Fig. 3 were obtained for a coil of 205

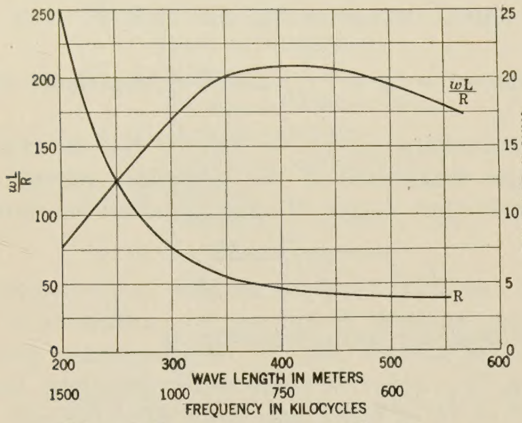

FIG. 3—RESISTANCE OF 205 μh. COIL

microhenrys, composed of 54 turns of No. 22 d. c. c. wire wound on a 3-in. tube. The values include the resistance of the tuning condenser. In Fig. 4 is shown the calculated variation in amplification with mutual

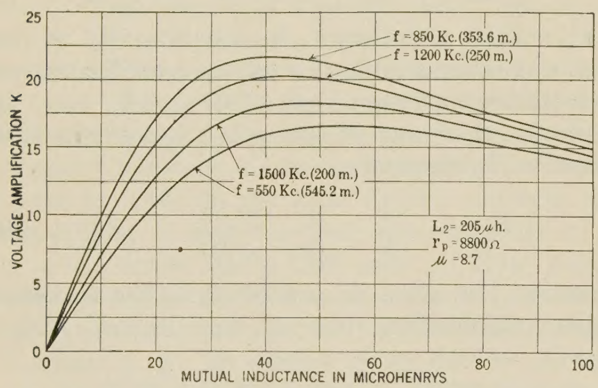

FIG. 4—VARIATION OF AMPLIFICATION WITH MUTUAL INDUCTANCE

inductance for four different wavelengths, using the values of resistance from Fig. 3. The constants used were of a $U\ X\ 201\ A$ tube which had an amplification constant of 8.7 and a plate resistance of 8800 ohms with 90 volts impressed on the plate and zero grid bias. As will be seen, the amplification curves have rather dull maxima. This shows that little gain in amplification would be obtained by varying the coupling between primary and secondary with the tuning, if sufficient coupling is initially employed.

The effect of mutual inductance on selectivity is shown in Fig. 5. In order to make a better comparison, in Fig. 6, the relative amplification K'/K is plotted against frequency, where K is the amplification at the resonant frequency and K' is the value at the frequency in question. As will be observed, the sharpness of resonance increases as the coupling is reduced, approaching the resonance curve of the secondary circuit as a limit as the coupling approaches zero. Satisfactory transmission of music requires a band of frequencies from approximately 50 to 5000 cycles. The process of modulation at the broadcasting station converts this band into a frequency spectrum of about 10 kilocycles in width, with the carrier frequency located in the center. Consequently, if faithful reproduction is to be secured, the amplitude relations existing between the various frequencies should be unchanged by the

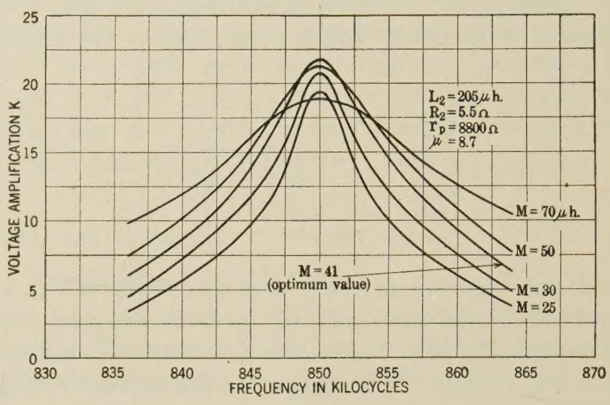

FIG. 5—VARIATION OF AMPLIFICATION WITH FREQUENCY

amplifier. In Fig. 6 it will be observed that in the lowest curve, which corresponds to coupling of 25 microhenrys, the amplification 5 kilocycles from the carrier wave is reduced to 54 per cent. If four such stages were used in cascade and all carefully tuned to the carrier frequency, the amplification 5 kilocycles

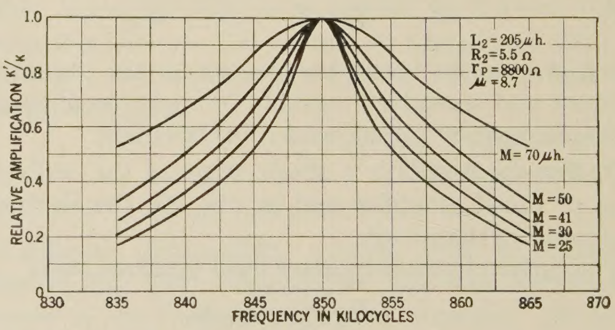

FIG. 6—EFFECT OF COUPLING ON SELECTIVITY

from resonance would have fallen to 8.5 per cent of the resonant value.

This attenuation of the side-bands materially impairs the quality of reception; consequently, in multistage amplifiers, a broader resonance curve per stage should be employed than would be used in an amplifier of fewer stages. The relative amplification characteristics of a multi-stage amplifier may be readily obtained from the curves of Fig. 6, since this factor for n stages

becomes $\left(\frac{K'}{K}\right)^n$. As the maximum value of the ordinate is unity, the selectivity greatly increases with the number of stages and with a resultant increase of side-band attenuation. This might lead to the conclusion that the fewer the number of stages employed the better would be the quality. That this is not the case is shown in Fig. 7. Curve A shows the relative

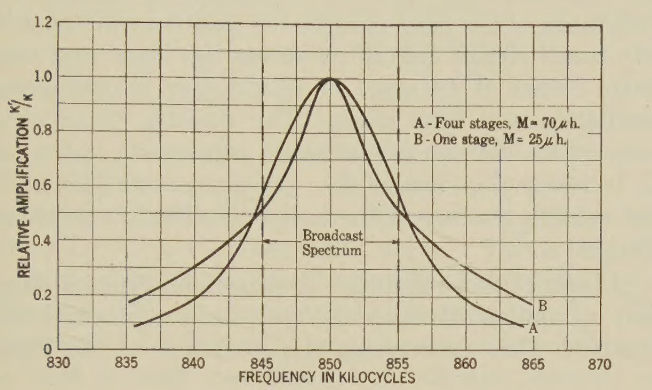

Fig. 7—Effect of the Number of Stages on Selectivity and Fidelity

amplification that would be obtained using four stages with $M = 70$ (the top curve of Fig. 6); while curve B is for a single-stage with $M = 25$ (bottom curve of Fig. 6). It will be noted that the side-band attenuation is less in the case of the four-stage amplifier than for the single-stage throughout the entire 10-kilocycle band, and the selectivity has been materially improved.

The ideal characteristic would be one which is flat-

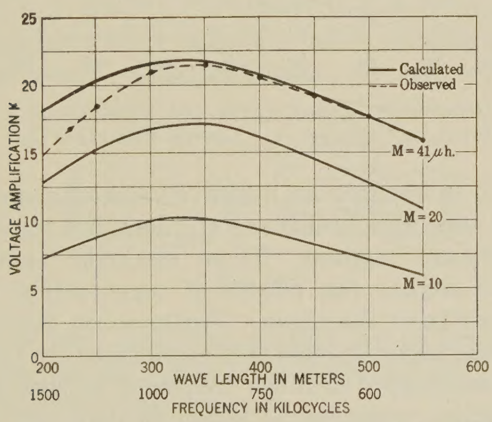

Fig. 9—Variation of Amplification with Wavelength for Various Values of Coupling

topped for an interval of about 10 kilocycles and then falls off very rapidly on either side of this interval. The fidelity would then be constant, irrespective of the number of stages employed.

Fig. 7 shows the relative amplification for a single-tuned stage at frequencies of 1500, 850 and 550 kilocycles, using the same coil and tube as in the preceding curves and a fixed value of mutual inductance of 25 microhenrys. As will be observed, this value of coupling is producing serious side-band attenuation at the lowest frequency, whereas at the high-frequency, or short-wave end of the broadcasting band, the response curve is too broad to give good selectivity. Broadening the individual response curve and increasing the number of stages will alter the shape of the over-all characteristic as in Fig. 7, but with a fixed value of coupling, good fidelity at the longer wavelengths can be obtained only at the expense of selectivity at the short wavelengths. Experimental receiving sets were constructed, incorporating this feature, with a view to determining approximately how much side-band attenuation could be tolerated before appreciable distortion or loss of natural quality was observed. It was found to be extremely difficult to obtain any quantitative data by means of audition tests as the opinions of the various observers differed quite widely. The only conclusion that could be drawn was that the amount of side-band attenuation that could be tolerated was surprisingly high. Some compensation can be obtained by designing the audio-frequency amplifier to have a rising characteristic so as to give greater amplification

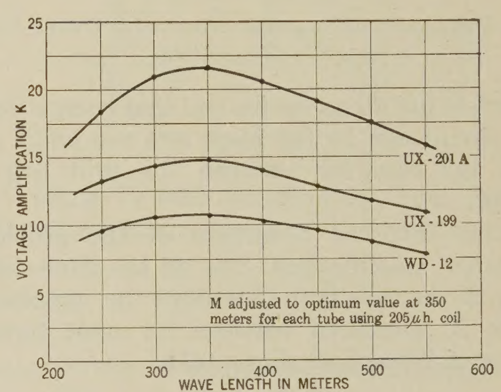

Fig. 10—Variation of Amplification with Wavelength for Various Tubes

at the higher frequencies. Exact compensation by this latter method is not possible, as the amount of side-band attenuation is much greater for the long wavelengths than for the short.

The variation of the amplification with wavelength for several values of mutual inductance is given in Fig. 9, together with the values obtained by actual test using a vacuum-tube voltmeter. Very close agreement is obtained except at the higher frequencies. The discrepancy in this region is due to the effect of capacity coupling between primary and secondary, which is not taken into account in the calculated values.

Fig. 10 shows the observed variation in amplification with wavelength for several types of tubes, the mutual inductance being adjusted to the optimum value at 350 m. in each case. This affords an interesting comparison of tubes designed for dry cell operation with the storage battery type. In Fig. 11 is shown the effect of various values of plate voltage upon the amplification. The variation in K is due only to

variation in the constants μ and r_p of the tube with plate voltage.

When several stages of amplification are used in cascade, difficulties are encountered due to the tendency of the individual stages to break into oscillation, especially if the amplification per stage is much above unity. This is due to the fact that the vacuum tube is

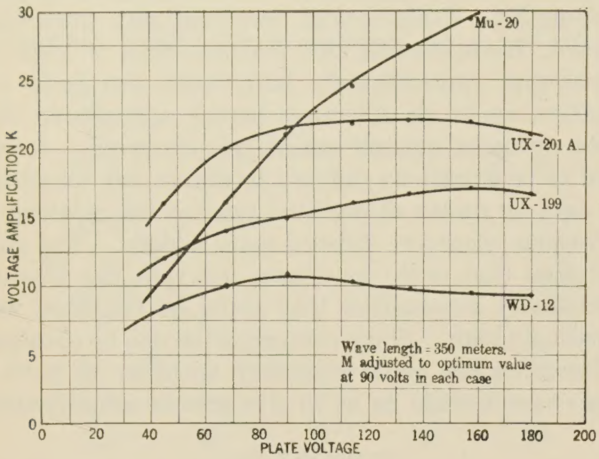

Fig. 11—Variation of Amplification with Plate Voltage for Various Tubes

not a perfect unilateral device and that energy from the output circuit can be fed back into the input circuit through the capacity between the grid and plate electrodes.

A rather involved treatment of the problem of regenerative amplification due to the inter-electrode capacity of the tube is to determine the impedance of the tube Z_g measured between its input terminals. The value of Z_g has been shown to[2] be

$$Z_g = \frac{1}{j\,\omega\,C_{gp}}\;\frac{1 + j\,\omega\,C_{gp}\,\dfrac{r_p\,Z_b}{r_p + Z_b}}{1 + j\,\omega\,C_{gp}\,\dfrac{r_p\,Z_p}{r_p + Z_b} + \dfrac{C_{gp}}{C_{gf}}\left(1 + \dfrac{r_p^{\,2}\,Z_b}{r_p + Z_b}\right)} \tag{11}$$

where the various quantities are indicated in Fig. 12.

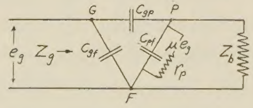

Fig. 12

In comparison with r_p the capacity between plate and filament C_{pf} has been neglected, which can be done without very great error provided the frequency is not too high. If the output circuit Z_b contains sufficient inductance, the impedance looking into the input terminals of the tube is of the form

$$Z_g = -\,r_g + \frac{1}{j\,\omega\,C_g} \tag{12}$$

If Z_b is a pure resistance or contains capacity reactance, the sign of r_g is positive.

Therefore, if the impedance in the plate circuit contains sufficient inductance reactance, the negative resistance of the tube reduces the positive resistance of the tuned circuit connected across the input and may even reduce it to zero, in which case a continuous oscillation will take place. The positive value of r_g that exists for non-inductive or condensive values of Z_b increases the value of R_2. All three conditions of Z_b can exist in the case of the tuned amplifier, as shown in Fig. 13.

It is much more desirable to secure inherent stability, and a number of methods have been evolved to accomplish this. Increasing the resistance of the input

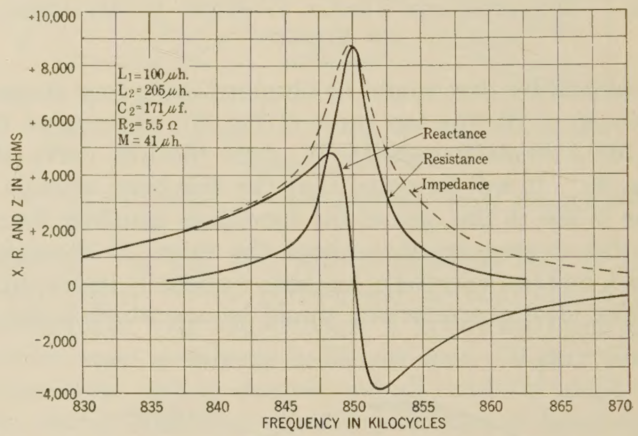

Fig. 13—Impedance Looking into the Primary of a Tuned Coupled Circuit at Various Frequencies

circuit, so as to offset the negative value of r_g and keep the total resistance positive at all times, is a convenient but inefficient method. These methods merely attempt to reduce the effects of regeneration rather than to strike at the cause. Furthermore, the magnitude of the negative resistance introduced by the tube varies considerably with the frequency so that if sufficient positive resistance is added to take care of the worst condition, too much will be present for the remainder of the time with the attendant loss of amplification and selectivity.

These objections have lead to the development of a number of bridge types of circuits, so called because of their similarity to the a-c. wheatstone bridge. The first of these, due to C. W. Rice,[3] is shown in Fig. 14,—*A* being the actual circuit and *B* the electrical equivalent omitting the tube electrodes. An inspection of the latter figure indicates that no voltage can exist across the input terminals *g n*, due to a voltage between *f p*

2. H. W. Nichols, *Phys. Rev.*, Vol. 13, p. 405, 1919: J. M. Miller, Bureau of Standards, *Bulletin No. 351.*

3. U. S. Patent No. 1334118.

if the arms are balanced. Hence, the energy which is fed back through C_{gp} is opposed in phase by that which flows through C_n. These conditions for a balance are:

$$\frac{L_a}{L_b} = \frac{C_n}{C_{gp}} \tag{13}$$

This balance is not entirely independent of frequency, as

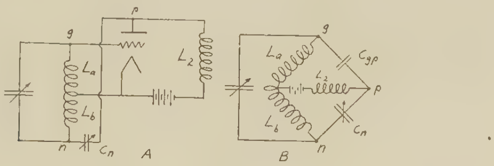

FIG. 14

equation (13) would indicate, unless the coupling between L_a and L_b is substantially unity. This is because L_a is shunted by the input capacity of the tube, C_g in equation (12), or more strictly speaking, by Z_g. To compensate for this, it is sometimes necessary to shunt L_b with a small condenser or a suitable network to

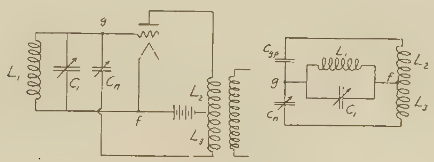

FIG. 15

simulate C_g, if stability is to be maintained over a wide frequency range or if the mutual inductance between L_a and L_b is small. Fortunately, exact balance is not required, but merely enough to insure stability throughout the range of frequencies to be covered. As a

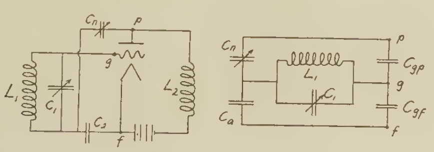

FIG. 16

matter of fact, some regeneration can be employed to advantage at the higher frequencies and thus increase the selectivity in this region.

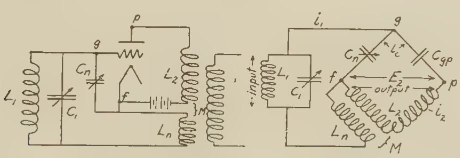

FIG. 17

A similar type of circuit, due to Hazeltine[4] is shown in Fig. 15.

4. U. S. Patent, Nos. 1489228, 1533858; *Proceedings* I. R. E. Vol. 14, 1926, p. 217.

The conditions for a balance are:

$$\frac{L_2}{L_3} = \frac{C_n}{C_{gp}} \tag{14}$$

A somewhat different type of circuit is given in Fig. 16. The input circuit $L_1 C_1$ is connected across the grid-filament terminals through the condenser C_a. The capacity C_{gf} is utilized as well as C_{gp}, the two forming a pair of ratio arms in a bridge composed entirely of condensers. A small variable capacity C_n is used to balance the circuit, the conditions for which are:

$$\frac{C_n}{C_a} = \frac{C_{gp}}{C_{gf}} \tag{15}$$

In practise, a resistance of about 250,000 ohms is shunted around C_a in order to prevent the accumulation of a negative charge on the grid, with the possibility of blocking the tube.

A circuit involving the principle of a mutual inductance bridge is shown in Fig. 17. In order that the

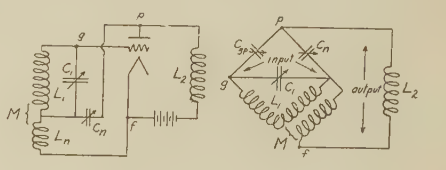

FIG. 18

output voltage E_2 shall not affect the input circuit, the conditions for a balance are:

$$\frac{M}{L_2} = \frac{C_{gp}}{C_{gp} + C_n} \tag{16}$$

Another circuit involving the same principles, except that the coil L_b is coupled to the input circuit instead of the output, is shown in Fig. 18. The conditions for balance are similar; namely, that $\dfrac{M}{L_1} = \dfrac{C_{gp}}{C_{gp} + C_n}$ (17)

The author wishes to express his appreciation to Mr. C. E. Fay, formerly of the Graduate School, for his assistance in obtaining some of the data.

PHONOGRAPHS TO BE OPERATED BY FILMS

Dr. W. R. Whitney, Director of Research of the General Electric Laboratories at Schenectady, N. Y., has announced that work is being conducted there, on a long-running phonograph, operating with films recording sound by light and shadow instead of operating with wax records in which the sound waves are registered by minute indentations in the wax. Dr. Whitney said that the long-running film could be used for the reproduction of entire operas or symphonies or for recording entire books orally, and that it might be possible to produce a film to sell for $6 which would read aloud for two hours.—*Tel. and Tel. Age.*

Abridgment of

Protection of Supervisory Control Lines Against Over-Voltage

BY EDWARD F. W. BECK[1]

Synopsis.—*Supervisory control lines used in the remote or automatic control of electric plants are subject to overvoltages dangerous to insulation and to operators. These overvoltages may be caused by lightning, crosses with the power lines, or induction from them. Open wire control lines are influenced by all of these, cables with grounded sheaths are immune to disturbances caused by lightning or other electrostatic induction, and are more or less safe from crosses. However, the ordinary cable is still subject to high voltages by electromagnetic induction when a fault occurs on the power line.*

These voltages may be dangerous not only to apparatus, but also to the cable insulation. Protection by means of lightning arresters is therefore necessary. Calculations show that even if the apparatus locations are protected, high voltages may occur along the line if the transmission line fault is between stations. This may cause a cable failure. It may, therefore, be advisable to protect the cable at certain intervals.

Supervisory control protectors may be called upon to discharge heavy currents of appreciable duration. This requires extremely sturdy arresters. The requirements are met by a spark-gap of special design in argon at a reduced pressure.

Specially made cables will shield the line against extraneous disturbances. In large installations, the use of such cables may be worthy of consideration.

THE supervisory control line is usually of the same nature as a telephone lead, consisting of the necessary number of pairs of wires either strung in open wire lines or in cable.

An open wire line is exposed to more severe disturbances than is a cable. Overvoltages in such a line may occur from the following causes:

1. Atmospheric electricity and lightning discharges.
2. Direct crosses with high-voltage lines.
3. Potentials above ground caused by electrostatic or electromagnetic induction from neighboring power lines.

In the following, certain calculations have been made to illustrate the order of the voltages which may be caused by induction. In these calculations, approximations have in general been used. These introduce a certain degree of error particularly at close spacings. However, in this discussion it is not justified to resort to exact methods; because first, the spacings encountered are usually large so that the discrepancy between the exact and approximate methods are not very great;

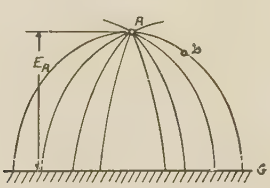

Fig. 1—Diagram Showing How Voltage is Induced Electrostatically on Supervisory Line

second, we are interested in whether the order of the potentials to ground are hazardous or not—that is, of the order of hundreds of volts or only a few volts; and third, there are so many variables involved in practise that even exact calculations do not always lead to accurate results. It is not necessary to be as meticulous as would be the case were communication circuits concerned, in which case very small disturbing voltages between wires might cause interference with the service.

If the line is open wire, disturbances may be caused either electrostatically or electromagnetically. Electrostatic induction will occur in the following way:

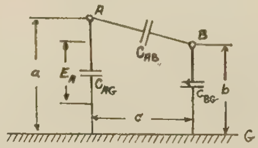

Fig. 2—Schematic Diagram of Conditions in Fig. 1

In Fig. 1, A is a conductor charged to a certain voltage E_A, and B is a nearby conductor, such as a supervisory line entirely insulated from ground. Between A and earth, G, there will be an electrostatic field due to the potential E_A. Some of the electrostatic lines between A and G will terminate on B, imparting to it a certain charge and therefore a potential above ground.

For an approximate solution, with the total number of lines of force between A and G known, a parallel plate condenser may be substituted for line and ground having the same number lines of force between its plates as pass from A to G, when the plates are at a difference of potential E_A. In the same manner, condensers may be inserted between A and B, and B and G. The capacities of such hypothetical condensers are known as the capacity of A to ground, A to B, etc. Thus, Fig. 1 may be replaced by Fig. 2. This facilitates the derivation of the induced potentials. Calculating the impedances of the circuit involved, the charging currents and the potentials may be found.

On a three-phase power system, the conditions are

1. Electrical Engr. Supply Div., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Feb. 13-18, 1928. Complete copies upon request.

similar provided the phase voltages are unbalanced. Ordinarily, the configuration of the wires of the transmission line and the location of the supervisory line will be such that the electrostatic field resultant of the three phases, when the voltage is balanced, is small.

If a fault occurs on the transmission line so that the voltages are no longer balanced, there will be a pronounced electrostatic field causing an induced voltage to appear on the control line. If the substitution of condensers is made as outlined in Fig. 2, the

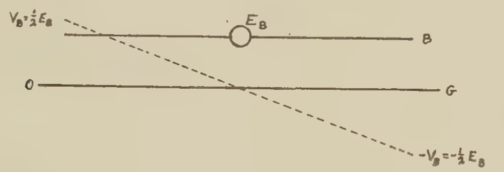

Fig. 3—Distribution of Potential on Line Isolated from Ground

distribution of charging currents and the induced voltages set up in the control line may be derived. The maximum induction takes place when a ground fault occurs on one phase of the transmission line.

The presence of grounded conductors near the control line will materially reduce the induction due to the increase in the capacity to ground of the control line, C_{BG}, in Fig. 2. By far the most effective manner of shielding the control line against electrostatic induction due either to the transmission line or lightning is the running of the line in metallic sheathed cable with the sheath grounded. The line is then immune to such influences.

The lead sheath of a cable, unfortunately, does not provide a perfect shield against electromagnetic induction, although it may reduce its effect appreciably.

Consider a single-phase transmission line with ground return and a neighboring control line consisting of a single isolated wire paralleling the transmission line. When the current enters the earth from one electrode, most of the current flows at a great depth. In order to make the calculations practical, it is necessary to assume a current path confined to a horizontal plane somewhere in the earth, the distance between it and the line being such that the flux included in the theoretical area so formed is of the same value as that actually generated by the transmission line current. This theoretical current-carrying plane is called the equivalent ground plane.

Having established what the circuit shall be, it is possible to proceed to the methods of calculating the electromagnetic induction. Under the above assumptions it can be shown that the e. m. f. induced in a unit length of control line is expressed by this formula:

$$e = 0.00466 \times f \times \log\left(\frac{2\,h}{d}\right)$$

e is the induced voltage per mile of exposure per ampere of current in the disturbing transmission line.

f is the disturbing frequency.

h is the height of the disturbing line above the equivalent ground plane.

d is the spacing between lines expressed in the same units as h.

Experience shows that in most cases, the maximum depth that may be expected is approximately 500 ft., so that calculations made with this value for h give in nearly every case values of induced voltage which are amply high.

Hence, the equation for induced voltage may be written:

$$e = 0.00466\, f \left(\log \frac{1000}{d}\right) \text{ volts per ampere mile,}$$

where d is in feet.

After establishing what the induced e. m. f. is, the control line may be considered as a circuit containing reactance and resistance depending upon the constants of the line, and a source of potential whose e. m. f. is the induced voltage.

In order to determine the potential to ground due to electromagnetic induction, consider the disturbed line by itself, with a source of e. m. f., E_B induced in it. If the control line is totally isolated from ground, the current which flows is chiefly a charging current.

The voltage between line and ground at any point is dependent upon the capacity between line and ground. If this capacity is evenly distributed, it is apparent that the potential to ground, V_B will be distributed as in Fig. 3.

The voltage to ground at the middle of the exposure is zero at each end of the line it is $\frac{1}{2}\,E_B$.

If the control line is grounded at one end but open at

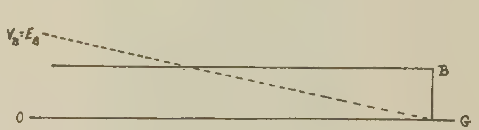

Fig. 4—Distribution of Potential on Line Grounded at One End

the other, the V_B of the grounded end is zero and the total voltage is thrown on the open end. (Fig. 4).

If the line is grounded at both ends, a short circuit is thrown on the induced e. m. f., E_B. A current will flow determined by the impedance of the circuit. Assuming zero ground resistance, the current is $\dfrac{E_B}{Z}$.

In this case the voltage to ground of the line is zero, and therefore grounding the line at both ends of the exposure is the best safeguard against overvoltage. This cannot actually, be done but can be accomplished in effect by connecting protectors between line and

ground at or near the ends of the line. If the induced voltage is high enough to discharge the protectors—about 350-500 volts—the line is effectively grounded for the duration of the fault on the transmission line. If the induction is not sufficient to break down the protectors, the potential on the line will distribute itself as in Fig. 3, but no damage will result.

The current which the protectors may be called upon to pass under fault conditions in the transmission line may reach high values for an appreciable duration of time, which requires extremely sturdy arresters.

In the foregoing, it is assumed that the fault in the transmission line is at one end of the exposure, so that the direction of the induced voltage is everywhere the same. Should the accidental ground on the power line occur anywhere between the ends, (for instance near the middle of the parallel), current will feed into the fault from both sides. These currents will be in opposite directions; hence the e. m. fs. induced in the sections of the control line on either side of the fault will be in opposition. The current which then flows in the control line ground loop when the protectors at the ends discharge will be a function of the resultant e. m. f. in the line. If the fault should occur midway between power sources of equal capacity, the resultant

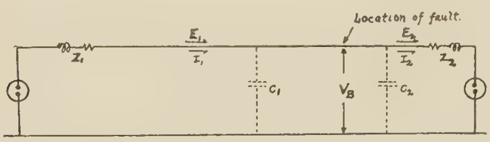

Fig. 5—Diagrams Showing Fault at Intermediate Point

e. m. f. is zero and no current flows. This does not mean that no voltage to ground appears on the control line. The two induced e. m. fs. oppose each other and the line has distributed capacity to ground. Therefore a voltage will pile up on the control line at a point opposite to the fault on the transmission line. This voltage may reach a considerable value, and if such is the case, a protector at or near that point is desirable. If a fault occurs somewhere within the parallel, the situation is as pictured in Fig. 5.

Z_1 and Z_2 are the impedances in the lines I_1 and I_2, the currents, and C_1 and C_2 represent the distributed capacities. The voltage to ground, V_B at the fault location will be $V = E_1 - I_1 Z_1 = E_2 + I_2 Z_2$, *i. e.*, less than the greater of the induced e. m. fs. but more than the smaller.

The voltage distribution will be as in Fig. 6.

a = is the point opposite the fault in transmission line.

$a\,b = E_1$.

$b\,c = E_2$.

$a\,c = a'\,c' = E_1 - E_2 = I\,Z$ in the line.

When the protectors discharge, there can be no potential to ground at a', so the ground potential will take the position $o\,c'$. The voltage to ground at a will then be $V = b\,d$. The ordinates between $o\,b$ and $o\,c'$ represent the distribution of the voltage to ground along one section; those between $b\,c'$ and $o\,c'$ that along the other.

The above discussion has dealt with a single-phase ground return power line, such as a railway trolley. On a three-phase system where the voltages are balanced, there will not be any magnetic field to speak of, and no

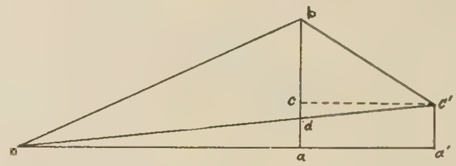

Fig. 6—Voltage Distribution with Fault as in Fig. 5

induction is to be expected on the control line. If the voltages are unbalanced, unbalanced earth currents will flow and an e. m. f. will be electromagnetically induced on the control line.

Electromagnetic induction from ungrounded systems is usually not severe. If an accidental ground occurs on one phase, the line currents will be unbalanced, a high voltage will appear between the ungrounded phases and ground, and a certain ground current will flow. This current is generally small. The induction is heavy only for high line voltages and long exposures or in such extreme cases as a double fault on two phases. Ordinarily, therefore, the induction on supervisory cables used in conjunction with ungrounded systems will not be hazardous when the fault occurs on one phase only.

However, on systems with a grounded neutral, high voltages may be induced, as heavy fault currents will flow in the case of an accidental ground. Since it is difficult to lay down a general solution for the protective problem, each installation consisting of power and control line presenting an individual question, it

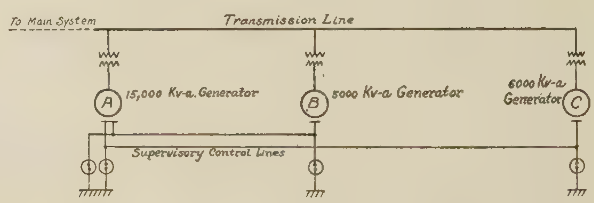

Fig. 7—Example of System with Supervisory Control

may be well to work through a hypothetical case in order to clarify the matter. The calculations made will serve as an indication of what may be expected and as a guide to the methods to be applied in the investigation of actual installations.

With this in view, consider a system as depicted in Fig. 7. In Fig. 7, B and C are two hydroelectric stations operated by supervisory control from a third station, A. These stations feed power into a system at 60 cycles through a 33,000-volt line, with the neutral grounded at each station. The generators and transformers at A, B, C have reactances of 20 per cent and 10 per cent, respectively. The capacities of A, B, and C are 15,000-, 5000-, and 6000-kv-a. The transmission line is No. 00 B & S. gage copper with a triangular spacing of 36 in. B is 4 mi. from A, and C is 5 mi. from B. The supervisory line is a cable spaced 15 ft. from the transmission line. It consists of 10 pairs of No. 19 B & S. wires running between A and B and 10 pairs from A to C. The cable between A and B thus contains

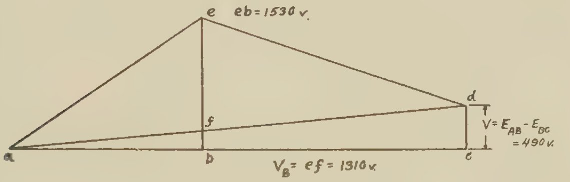

Fig. 8—Voltages Induced in Control Line Shown in Fig. 7 with Power-Line Fault at B

20 pairs of wires. At each end of each line, each conductor is connected to earth and cable sheath through a protector.

Then $e = 0.51$ volts per ampere-mile and the problem resolves itself into a calculation of the ground current.

Let us first assume the fault,—a ground on one phase,—to be at B. The calculations are easily made by the phase sequence method, following the procedure described by R. D. Evans (see bibliography).

Suppose the protectors have broken down so that $A - B$ is grounded at A and B and the line from A to C at A and C. Then the currents induced will be:

$$I_{AB}' = \frac{1530}{4 \times 44} = 8.7 \text{ amperes.}$$

$$I_{AC}' = \frac{490}{9 \times 44} = 1.2 \text{ amperes.}$$

Because of the fact that the e. m. fs. induced in $A - B$ and $B - C$ are in opposition, a voltage to ground will exist on the line $A - C$, with a maximum at B. This voltage is indicated by Fig. 8.

The voltage at B is $e\,f = 1310$ volts.

Because the line $A - B$ has protection at B, its voltage to ground at B is zero and, therefore, there may be a potential of 1310 volts between the conductors of the line $A\,B$ and those of the line $A - C$. This is a hazard. Consequently, in this case, protectors should be installed on the line $A - C$ at or near B. The voltage $E\,F$ will then collapse. The protectors on $A - C$ at B will be called upon to discharge a current of

$$I_B' = \frac{1530}{4 \times 44} + \frac{1040}{5 \times 44} = 13.5 \text{ amperes.}$$

While the above described example may serve to indicate the nature of the induced voltages, much higher ones may exist, particularly where large connected systems can feed into the ground fault, thus causing the flow of very heavy ground currents. On the other hand, there are fortunately certain conditions which act to reduce the electromagnetically induced voltage so that the results obtained for the particular case calculated are possibly pessimistic. The proximity of grounded conductors exerts a shielding effect. The use of an overhead ground wire, or a neutral wire on the transmission line, may reduce the induction considerably, since an appreciable part of the fault current will flow through this wire instead of through the earth, whereby the area of the disturbing loop, and therefore the inducing flux, are considerably decreased. The cable sheath itself, if well grounded, may be a potent reducer of induced e. m. f. The cable sheath acts as a short-circuited damping turn. The degree of damping which it exerts depends upon the

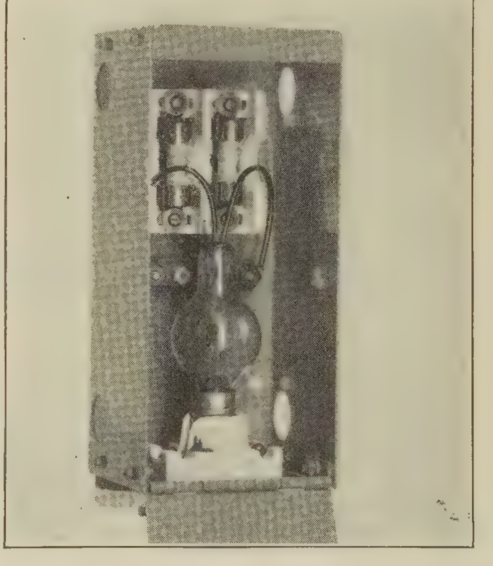

Fig. 9—Supervisory-Control Protector Unit

phase angle of the sheath. For effective shielding, it is important that the reactance of the sheath ground loop be as high as possible in comparison to its resistance.

Where the sheath resistance is appreciable, the shielding effect will be small. In the case of the 20-pair cable between A and B, in Fig. 7, the sheath resistance is

4.2 ohms per mile, while the 60-cycle reactance is 1.2 ohms per mile. Hence, the phase angle and the shielding effects are quite small. For larger cables, where the sheath resistance is lower, the shielding effect is much greater. To obtain the best shielding effect, telephone cables have been constructed in which a shell consisting of a number of copper wires is located next to the lead sheath, these wires being solidly grounded at each end of the cable; also, with iron hoops around the sheath to increase the reactance. If shielding of this kind is resorted to, it is theoretically possible to forego entirely the use of protectors.

A special protector has been developed for use on supervisory control circuits to relieve lightning voltages and with sufficient capacity to discharge the heavy currents of comparatively long duration which may be caused by induction. The essential element of this device is a spark-gap of particular design, enclosed in an atmosphere of inert gas at a reduced pressure, to give a low breakdown voltage. The gas used permits of large energy discharges without undue injury to the electrodes which are of arc-resisting material. The breakdown voltage of the gap is of the order of 350 to 500 volts. The protector has four electrodes equally spaced from each other, so that several lines may be protected simultaneously.

The complete protector consists of the bulb herein described, mounted in a steel box with a pair of low-voltage, low-capacity fuses, and a terminal block. This device is shown by Fig. 9.

The protector bulb is capable of discharging lightning voltages of any order except direct strokes nearby, and will handle many times discharges of 50 amperes of two seconds' duration. It will take care of heavier discharges, but at a sacrifice of length of life. It will discharge several hundred amperes, thereby keeping the voltage on the line below hazardous values even if it is destroyed by so doing.

Abridgment of

Vector Calculating Devices

BY M. P. WEINBACH[1]

Associate, A. I. E. E.

***Synopsis.**—In the analysis or solution of a-c. problems, it is frequently necessary to convert vector quantities from the exponential or polar form into complex numbers, or vice versa. This paper describes:*

a. A device by means of which such conversions may be performed mechanically.

b. A device by means of which vector quantities expressed exponentially may be added or subtracted without prior conversion into the complex numbers.

c. A slide rule with trigonometric and hyperbolic scales so disposed that conversions of vector quantities from one mathematical form into another, or the evaluation of trigonometric or hyperbolic functions of complex variables may be obtained with ordinary slide rule ease and rapidity.

THE object of this paper is to describe some mechanical devices which may be used to simplify vector calculations and thus save time and economize in mental labor.

It is well known that harmonically varying voltages and currents may generally be expressed in three mathematical forms. Each of the three expressions leads to a distinct physical interpretation and is conveniently adapted to particular processes of analysis or calculations. Thus, the expression $V \sin \omega t$, for a harmonically varying voltage, and $I \sin (\omega t \pm \theta)$ for a similarly varying current, visualize the sinusoidal variations of the respective quantities. They are clearly well adapted to the analysis of problems in which instantaneous values are of particular significance.

The exponential forms $V e^{j\omega t}$ and $I e^{j(\omega t \pm \theta)}$ visualize harmonically varying voltages and currents, respectively, as vectors of definite lengths, either maxima or more generally effective values, rotating in a plane at uniform angular velocities ω radians per second. The angular positions of the respective vectors at any instant with reference to the particular instant when $t = 0$ fully define the magnitude of their instantaneous values. These exponential expressions for harmonically varying quantities are adapted to the mathematical processes of differentiation and integration.

If instead of instantaneous, the maxima or effective values are the significant quantities in the solution of a particular problem subject to analysis, the concept of vector rotation may be completely ignored, instantaneous time positions of the vectors discarded, and the vectors merely referred to one or the other in time phase. Under such conditions, voltage and current vectors may be expressed by $V e^{j0^\circ}$ and $I e^{j\theta}$, respectively, when the current is referred to the voltage in

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Presented at the Regional Meeting of the A. I. E. E., St. Louis, Mo., March 7-9, 1928. Complete copies upon request.

phase. These exponential or polar expressions visualize the vector quantities as vectors in fixed positions in a plane. Thus, a translation from time to space vectors has been effected, but the angle θ must be thought of as actually a time-phase angle. These expressions for harmonically varying voltages and currents give actual numerical values of the vectors and their time-phase relationship with regard to a particular one, conveniently chosen as a reference. They lend themselves with great facility to the mathematical processes of multiplication, division, powers, roots, and logarithms.

The translation of time vectors to space vectors, as indicated above, led to the well-known graphical method of solution of a-c. circuit problems. The graphical method, however, becomes more or less complicated when applied to the solution of complex circuits. Its degree of accuracy depends upon the exact laying off of vectors with regard to magnitude and angular phase with respect to one another. The introduction of the algebraic method, involving the complex number of the form $a + j\, b$, expressing a vector quantity in terms of its components along the axes of the Cartesian system of coordinates, eliminates the inaccuracies inherent in the graphical method, but frequently at the expense of more time in arriving at the solution of the problem.

The complex number is the most generally used mathematical expression for vector quantities. It is the only vector expression that lends itself to the processes of addition and subtraction, subject to the algebraic laws governing complex numbers. Its universal application to the operations just mentioned has led to the stating of currents, for instance, not in terms of actual values and phase angles, but in terms of their components in phase with or in quadrature to the voltage producing them. It has led to the stating of impedances and of admittances not in terms of their actual values and phase producing angles, but in terms of their respective components. All this in spite of the fact that in direct tests, actual vector values are usually measured and not their components.

While for purposes of algebraic additions it is necessary to use the complex number, a vector quantity should always be stated in terms of polar or exponential expressions, since these give actual values as to quantity and phase relation. It follows, therefore, that conversions from one form to the other are essential and must frequently be made.

The addition of two vectors expressed as exponentials, and the reconversion of their sum into the exponential form, demands the looking up of five trigonometric functions, four multiplications, three additions, two squares, one square root, and one division, a total of sixteen operations. Obviously, in complex problems, the solution of which demands other mathematical operations than a single addition, the calculations become tedious and quite time consuming.

Fig. 1 shows a device for the rapid conversion of vector quantities from the exponential form to their equivalent complex numbers and vice versa.

The principle of the instrument is simply a mechanical generalization of the graphical solution of a right triangle.

Fig. 3 shows a device by means of which vectors expressed exponentially may be added or subtracted mechanically without resorting to conversion into complex numbers. Like the device shown in Fig. 1,

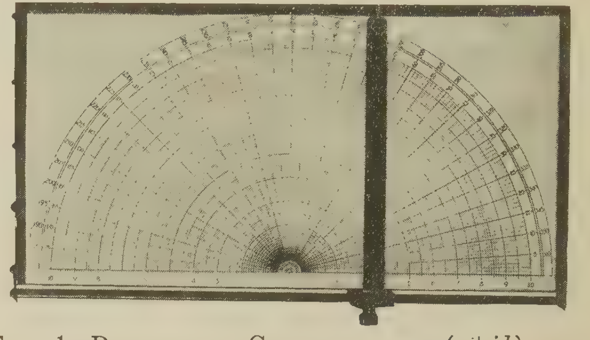

FIG 1—DEVICE FOR CONVERSION OF $(a+j\,b)$ INTO $A < \theta$ OR VISA VERSA

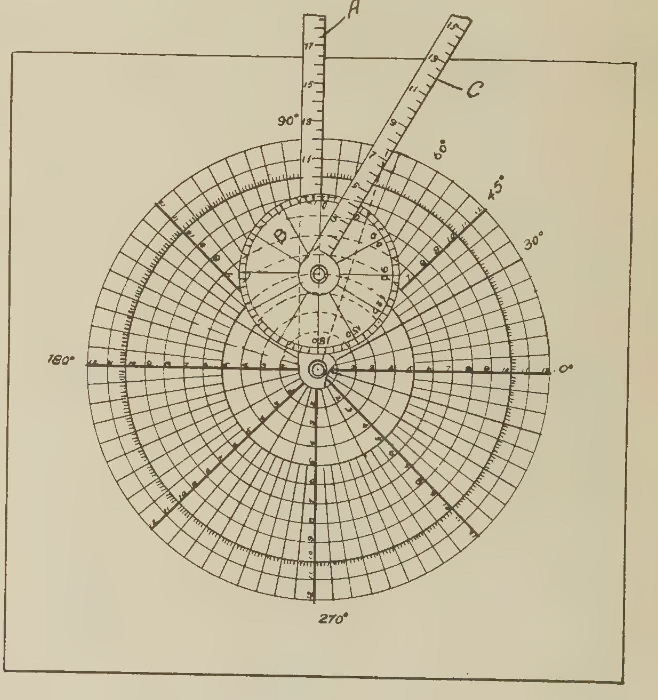

FIG. 3—DEVICE FOR MECHANICALLY PERFORMING THE OPERATION $M < \alpha \pm N < B$

this one is a mechanical generalization of the graphical solution of any triangle.

There is no particular novelty in the principles involved in these two calculating devices, possibly some in the structure and manipulation. Both have been used by the author and his students and have been effective economizers of time in the solution of a-c. circuit problems.

The Vector Slide Rule. Regarding accuracy, ease of manipulation, and convenient portability, neither of the

devices described above compares advantageously with the calculating device commonly known as the slide rule. The fundamental principles embodied in the ordinary Mannheim slide rule may be directly and effectively applied to plane vector operations, provided that suitable scales are chosen.

Fig. 7 shows such a slide rule. Like the ordinary slide rule, it consists of a body, a sliding member, and a running hairline indicator. On the upper part of the body there are three scales. Two of these scales are marked S. The first of these scales in conjunction with the regular scale D on the lower part of the slide rule gives the sines of angles from 5.7 deg. to 90 deg. The second, gives in conjunction with scale D the sines of angles from 0.7 deg. to 5.7 deg. The third scale marked T gives in conjunction with scale D the tangents of angles from 5.7 deg. to 45 deg., and cotangents of angles larger than 45 deg. Beneath scale D there is an inverse scale marked $C\,I$ on which may be read, in conjunction with scale T, the tangents of angles larger than 45 deg. and the cotangents of angles smaller than 45 deg. Since tangent values of angles less than 5.7 deg. are sensibly equal to the sines, the scale marked S for these angles may also be used as a tangent scale without serious error.

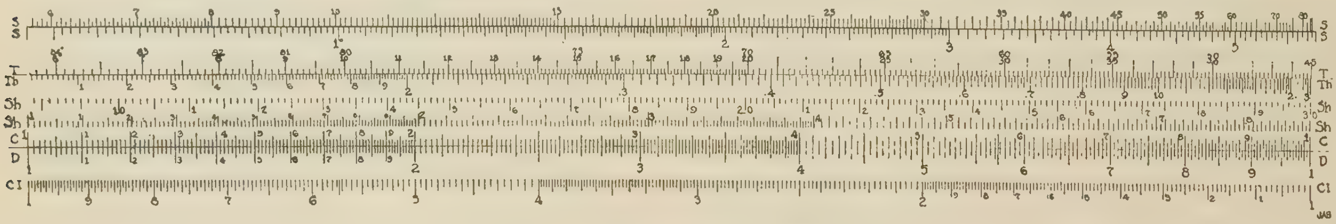

Fig. 7—Vector Slide Rule

On the sliding member of the rule, there are four scales; the upper one, marked $T\,h$, gives in conjunction with the regular scale C on this member, the hyperbolic tangents ($\tanh u$) for hyperbolic angles of value $u = 0.1$ to $u = 3.0$ hyperbolic radians. The next two scales marked $S\,h$ give in conjunction with scale C, the hyperbolic sines ($\sinh u$) for hyperbolic angles $u = 0.1$ to $u = 3.0$ hyperbolic radians. Since the hyperbolic tangent is sensibly equal to the hyperbolic sine, and both sensibly equal to the hyperbolic angle itself for angles less in value than $u = 0.1$ hyperbolic radians, scale C gives directly the hyperbolic angle, and also the hyperbolic sines and tangents for values of u less than 0.1 hyperbolic radians.

This slide rule, with the scales as indicated, may be used for the following operations:

1. Usual slide rule multiplications and divisions.
2. In lieu of trigonometric tables.
3. In lieu of hyperbolic tables for values of hyperbolic angles to 3.0 hyperbolic radians.
4. To evaluate exponential functions e^{-u} and e^{u} to values of $u = 3.0$.
5. For the rapid conversion of vector quantities from the complex form into equivalent exponentials.
6. For the rapid conversion of vector quantities from the exponential form into equivalent complex numbers.

Thus to convert, for instance, 8.5 $e^{j24.3}$ deg. into its equivalent complex number, since the real component is 8.5 cos 24.3 deg., set the hair line on scale S at 90 deg. − 24.3 deg. = 65.7 deg. This gives on scale D cos 24.3 deg. Set index of scale C under the hairline and move indicator hairline to 8.5 on scale C. The product 8.5 cos 24.3 deg. = 7.74 is read under hairline on scale D. The operation is identical for the determination of the imaginary component 8.5 sin 24.3 deg. = 3.5.

To convert a complex number of the form $a + j\,b$,

note that $$\frac{b}{a} = \tan\theta$$

and $$A = \frac{b}{\sin\theta}$$

where A is the numerical value of the vector and θ is its angular phase position with reference to the positive horizontal. Therefore, two simple divisions may replace the six operations involved in the determination of the vector value by the usual method

$$A\,e^{j\theta} = \sqrt{a^2 + b^2}\,e^{j\tan^{-1} b/a}$$

To convert, for instance, the complex number $4.55 + j\,3.72$ by the use of the slide rule into its exponential equivalent, set hair line on 3.72 scale D. Move the sliding member to bring 4.55 on scale C under the hair line, then the tangent of the phase angle is given on scale D, and the angle $\theta = 39.2$ deg. is read on scale T opposite the index of scale C.

To get the vector value A, set hair line over 39.2 deg., scale S, bring 3.72 on scale C under the hair line, and read the value of $A = 5.88$ on scale C, opposite index of scale D.

7. This slide rule may be used most effectively to evaluate hyperbolic or trigonometric functions of complex variables into equivalent plane vectors, either expressed exponentially or in terms of complex numbers. Such functions are frequently met in physical problems in which quantities involved are subject simultaneously to trigonometric and hyperbolic laws of variation; *i. e.*, they are growing or attenuating hyperbolically and simultaneously alternating harmonically. The mathematical expressions for such quantities in-

volve hyperbolic functions of the forms sinh $(u + j\,\theta)$, cosh $(u + j\,\theta)$ and tanh $(u + j\,\theta)$, or trigonometric functions of the forms sinh $(\theta + j\,u)$, cos $(\theta + j\,u)$ and tan $(\theta + j\,u)$, in which θ is a circular angle, generally stated in circular radians, and u is a hyperbolic angle stated in hyperbolic radians.

The "Kennelly Tables"[2] give the vector values and the equivalent complex numbers of the above mentioned functions for values of u in steps of 0.05 and values of θ in steps of 4.5 deg. Double interpolations are necessary, however, if the values of u and θ differ from those given in the tables.

For example, the numerical evaluation of the sine of such complex functions may be accomplished by either one of the following calculations:

$$\sinh(u + j\,\theta) = \sqrt{(\sinh u \cos\theta)^2 + (\cosh u \sin\theta)^2}\; e^{j\tan^{-1}(\tan\theta/\tanh u)}$$
$$= \sqrt{\cosh^2 u - \cos^2\theta}\; e^{j\tan^{-1}(\tan\theta/\tanh u)}$$
$$= \sqrt{\sinh^2 u + \sin^2\theta}\; e^{j\tan^{-1}(\tan\theta/\tanh u)}$$

The first of the above expressions involves the looking up of three hyperbolic functions, and four trigonometric functions, two multiplications, one division, two squares, one addition, and one square root, a total of fourteen operations. By the last two, the numerical evaluation of the function is reduced to ten operations.

The reason for avoiding such functions which are met in the solution of electrical transmission problems, and the preference generally given to approximate methods, is very evident. It takes quite an appreciable time and mental labor to evaluate even a single function.

The slide rule described above affords rapid calculation of any such functions for any value of u between the limits of 0 and 3.0 and for any value of θ. The circular member $j\,\theta$ may be neglected when the hyperbolic angle is larger than 3.0 hyperbolic radians, because $\sin^2\theta$ is insignificant in comparison with $\sinh^2 u$.

The application of the slide rule for calculating the hyperbolic sine or the trigonometric sine of complex functions is fundamentally based upon the fact that the numerical value of the function is $\sqrt{\sinh^2 u + \sin^2\theta}$.

This may obviously be thought of as the hypotenuse of a right triangle whose other two sides are $\sin\theta$ and $\sinh u$, as shown in Fig. 8. Referring to this figure, we note that

$$\frac{\sin\theta}{\sinh u} = \tan\alpha$$

or

$$\frac{\sinh u}{\sin\theta} = \tan\beta$$

Hence the hypotenuse of the triangle is

$$\sqrt{\sinh^2 u + \sin^2\theta} = \frac{\sin\theta}{\sin\alpha} = \frac{\sinh u}{\sin\beta}$$

Similarly, the numerical value of the function cosh $(u + j\,\theta)$ is $\sqrt{\sinh^2 u + \cos^2\theta}$. It may also be thought of as the hypotenuse of a right triangle, whose two other sides are $\sinh u$ and $\cos\theta$, as shown in Fig. 9. Referring to this figure it will be seen that

$$\frac{\cos\theta}{\sinh u} = \tan\phi$$

or

$$\frac{\sinh u}{\cos\theta} = \tan\psi$$

whence the numerical value of the function is

$$\sqrt{\sinh^2 u + \cos^2\theta} = \frac{\cos\theta}{\sin\phi} = \frac{\sinh u}{\sin\psi}$$

It is easily seen from the above that the minimum of six operations necessary to obtain the numerical values of either the sine or the cosine functions are reduced to only two simple slide rule divisions. The four operations necessary to determine the angles associated with the numerical values of either function are similarly reduced to only a single slide rule division

$$\frac{\tan\theta}{\tanh u} = \tan\delta$$

the angle δ being read directly on scale T.

To illustrate the above, consider the function sinh $(1.25 + j\,1.1)$ = sinh $(1.25 + j\,63$ deg.)

Since $$\tan\alpha = \frac{\sin 63\text{ deg.}}{\sinh 1.25},$$

set hair line on 63 deg. scale S. Bring 1.25 of scale $S\,h$ under the hair line; $\tan\alpha$ is then read on scale D, and the angle α = 29.1 deg. is read on scale T at the index of scale C.

Since $$\sqrt{\sinh^2 1.25 + \sin^2 63\text{ deg.}} = \frac{\sin 63\text{ deg.}}{\sin 29.1\text{ deg.}},$$

set hair line on 63 deg., scale S; bring value of sin 29.1 deg. on scale C under hair line, and read the numerical value 1.833 of the function on scale D at index of scale C.

To obtain the angle associated with the vector value of the function, since

$$\tan\delta = \frac{\tan 63\text{ deg.}}{\tanh 1.25}$$
$$= \frac{1}{\tan 27\text{ deg.} \times \tanh 1.25}$$

the value of the angle may be obtained directly by slide rule operations dictated by either of the above equations. Thus using the second equation, set index of scale C at 27 deg. scale T; move hair line to 1.25 scale $T\,h$, then (tan 27 deg. $\times$ tanh 1.25) is given on scale D, its reciprocal on the inverse scale $C\,I$, and the corresponding angle 66.6 deg. on scale T. The vector value of the function is therefore

$$\sinh(1.25 + j\,1.1) = 1.833\, e^{j66.6}\text{ deg.}$$

2. "Tables of Complex Hyperbolic and Circular Functions," A. E. Kennelly, *Harvard Univ. Press*, 1914.

The function cosh (1.25 + j 1.1) is evaluated in the same manner. Thus, referring to Fig. 9, since

$$\tan \phi = \frac{\cos 63 \text{ deg.}}{\sinh 1.25} = \frac{\sin 27 \text{ deg.}}{\sinh 1.25}$$

set hair line on 27 deg. scale S. Bring 1.25 of scale $S\,h$ under hair line, and read angle ϕ = 15.8 deg. on scale

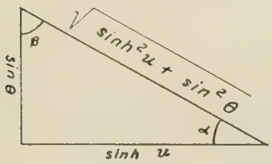

Fig. 8

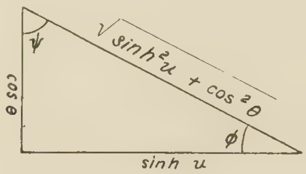

Fig. 9

Figs. 8-9—Principle of Slide Rule for Evaluating Sinh ($u + j\,\theta$) and Cosh ($u + j\,\theta$)

T at index of scale C. Then since the numerical value of the function is

$$\sqrt{\sinh^2 1.25 + \cos^2 63 \text{ deg.}} = \frac{\cos 63 \text{ deg.}}{\sin 15.8 \text{ deg.}} = \frac{\sin 27 \text{ deg.}}{\sin 15.8 \text{ deg.}},$$

set hair line on 27 deg. scale S. Bring value of sin 15.8 deg. on scale C under hair line and read value 1.663 of the function on scale D at index of scale C. The angle associated with the vector value of the function may be calculated either by slide rule multiplication represented by the equation

$$\tan \rho = \tan 63 \text{ deg.} \times \tanh 1.25$$

or by the slide rule division

$$\tan \rho = \frac{\tanh 1.25}{\tan 27 \text{ deg.}};$$

the value of ρ = 59 deg., being read directly on scale T.

The vector value of the function is, therefore

$$\cosh (1.25 + j\,1.1) = 1.663\, e^{j59} \text{ deg.}$$

The hyperbolic tangent of the function may now be obtained by direct slide rule division as indicated by the following operation

$$\tanh (1.25 + j\,1.1) = \frac{1.833\, e^{j66.6} \text{ deg.}}{1.663\, e^{j59} \text{ deg.}}$$

$$= 1.11\, e^{j7.6} \text{ deg.}$$

Abridgment of

Magnetic Leakage and Fringing Flux Calculations

BY WALTER L. UPSON[1] and ERNEST L. FURTH[2]

Member, A. I. E. E. Enrolled Student, A. I. E. E.

Synopsis.—*The object of this paper is the development of an empirical method of determining leakage and fringing fluxes in an electromagnetic system. Certain assumptions are made; namely, (a) the reluctance of the iron parts of the magnetic circuit are negligible as compared with that of the air-gaps; (b) the leakage and fringing components of the flux follow paths of convenient geometric shape.*

Formulas are derived for leakage and fringing fluxes as percentage of the main flux which crosses the gap from the pole face, for two cases, (1) a pole core of circular section and (2) one of rectangular section. Calculations of these fluxes, in percentage of the main flux, are given over a convenient range of gap lengths, coil lengths and distance of coil from pole face. It is seen that both leakage and fringing depend to a considerable extent on all these factors. Calculations are made to determine the flux density at various points along the core length and these show a wide variation in density in accordance with the dimensions of the magnetic circuit. An experimental check was made of certain of the calculated results, and the agreement obtained was as close as could be expected, the derivation being within the limits of error of observation.

The paper is not a complete discussion of the subject but it is hoped to develop it still further in a subsequent paper.

* * * * *

THIS paper outlines a practical method of calculating fluxes produced by a solenoidal winding on an iron core. It is assumed that there is a definite air-gap in the magnetic circuit and that the reluctance of the iron portions of the path is negligible in comparison with the reluctance of the air-gap. This assumption of negligible iron reluctance is admissable where low or medium magnetic densities are involved, but the method may also be utilized with advantage when densities are high.

The general plan is illustrated in Fig. 1, in which one sees a core surrounded by an exciting coil. There are two equal air-gaps, one at each end of the core, and the main flux passes across the gaps into large iron plate armatures. These armatures are assumed to be at the same magnetic potential as they would be if the magnetic circuit were completed through a path of zero reluctance.

The entire drop of magnetic potential is then taken

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Presented at the Regional Meeting of the A. I. E. E., St. Louis, Mo., March 7-9, 1928. Complete copies upon request.

as occurring across the two gaps. If the coil is considered as composed of two half-coils, each half-coil may be assumed to provide the magnetomotive force required to send the flux across one gap; and the amount of flux which crosses the gap is

$$\phi_g = M \times \frac{\text{pole-face area}}{\text{gap length}}$$

where M is the magnetomotive force of the half-coil. The half-coil is assumed also to set up leakage flux which passes from the core sides to the midplane as shown on the right-hand side of the figure, the lines

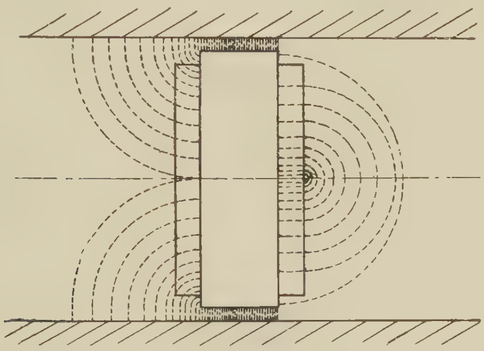

FIG. 1

continuing on into the core sides under the influence of the other half-coil. In addition to leakage, the half-coil sets up the so called fringing flux which passes out from the coil-side into the armature as shown on the left-hand side of the figure. While the magnetic lines of force do not follow accurately the paths as shown, they do behave in some such manner, and the calculation based upon such a conveniently chosen set of curves yields results which are substantially correct.

We may then confine the calculation to a single air-gap and a half-coil as shown in Fig. 2. Let the pole core be circular in section of radius 1, in any desired units, such as inches or centimeters.

Let h = height of the half-coil,
n = distance from the pole-face to the coil,
g = gap length,
t = coil thickness.

The problem is to calculate (1) the leakage flux, ϕ_L, and (2) the fringing flux, ϕ_F, both in percentage of the main flux, ϕ_g, which goes directly across the gap.

Each of these fluxes may be divided into two parts; one, that which passes through the coil, and the other, that which leaves the core side beyond the coil. Then

$$\phi_L = \phi_L' + \phi_L''$$
$$\phi_F = \phi_F' + \phi_F''$$

Calculation of ϕ_L', the leakage flux which passes through the coil (Fig. 2): This flux is assumed to follow the path, l_L', straight across the coil of thickness, t, then along a circular arc of radius, x. The length of this path is $l_L' = t + \frac{\pi}{2} x$

The area of the elementary cross-section of width, dx, is

$$d\,a_L' = 2\,\pi \left(1 + \frac{t}{2} + \frac{2\,x}{\pi}\right) dx$$

which is an approximate average area over the entire length l_L'.

Then $$d\,\phi_L' = \frac{x\,M}{h} \times \frac{2\,\pi\left(1 + \frac{t}{2} + \frac{2\,x}{\pi}\right) dx}{t + \frac{\pi}{2}\,x}$$

where $\frac{x\,M}{h}$ is that portion of the magnetomotive orce which acts to send flux along the path, x. The flux ϕ_L', expressed as a percentage of the main flux, ϕ_g, is

$$\%\ \phi_L' = \frac{\phi_L'}{\phi_g} = \frac{g}{h} \int_0^h \frac{2\left(1 + \frac{t}{2} + \frac{2\,x}{\pi}\right) dx}{t + \frac{\pi}{2}\,x},$$

since $\phi_g = \frac{M\,\pi}{g}$

$$= \frac{2\,g}{\pi}\left[2 + t + \frac{2\,h}{\pi} - \frac{8\,t}{\pi^2} + \frac{2\,t}{h\,\pi}\left(\frac{8\,t}{\pi^2} - 2 - t\right)\log\left(1 + \frac{\pi\,h}{2\,t}\right)\right] \qquad (1)$$

If t is negligible in comparison with h, (1) reduces to

$$\%\ \phi_L' = \frac{4\,g}{\pi}\left(1 + \frac{h}{\pi}\right) \qquad (2)$$

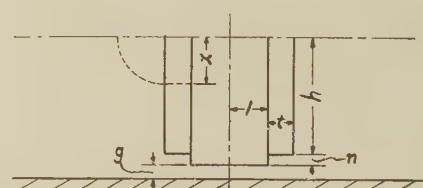

FIG. 2

Similar developments give the following equations for the fluxes ϕ_L'', ϕ_F' and ϕ_F''.

$$\%\ \phi_L'' = \frac{\phi_L''}{\phi_g} = \frac{4\,g}{\pi} \int_h^{h+n} \frac{\left(1 + \frac{2}{\pi}\,x\right) dx}{x}$$

$$= \frac{4\,g}{\pi}\left[\frac{2}{\pi}\,n + \log\left(1 + \frac{n}{h}\right)\right]$$

$$\%\ \phi_F' = \frac{4\,g}{\pi^3}\Bigg[(h\,\pi - 2\,n\,\pi - \pi^2 + 4\,B)$$

$$+ \left(\pi^2 + 2\,n\,\pi - 4\,B + \frac{4\,n\,B}{h}\right.$$

$$+ \frac{2\pi B}{h} - \frac{8 B^2}{h\pi} \Big) \log \Big(1 + \frac{\pi h}{2B} \Big) \Big] \qquad (6)$$

where $$B = \frac{\pi}{2} n + g$$

$$\% \phi_F'' = \frac{4g}{\pi} \Big[\frac{2}{\pi} n + \Big(1 - \frac{4g}{\pi^2} \Big) \log \Big(1 + \frac{\pi n}{2g} \Big) \Big]$$

Leakage and Fringing Fluxes from Rectangular Cores

Formulas for these important cases are derived in a manner exactly analogous to those for the round cores.

1. Percentage leakage flux through the coil is,

$$\% \phi_L' = \frac{g}{\pi d} \Big[\Big(2d + 4 + \pi t - \frac{8t}{\pi} + 2h \Big) - \frac{2t}{\pi h} \Big(2d + 4 + \pi t - \frac{8t}{\pi} \Big) \log \Big(1 + \frac{\pi h}{2t} \Big) \Big]$$

If the core section is square, this becomes

$$\% \phi_L' = \frac{g}{2\pi} \Big[\Big(8 + \pi t - \frac{8t}{\pi} + 2h \Big) - \frac{2t}{\pi h} \Big(8 + \pi t - \frac{8t}{\pi} \Big) \log \Big(1 + \frac{\pi h}{2t} \Big) \Big]$$

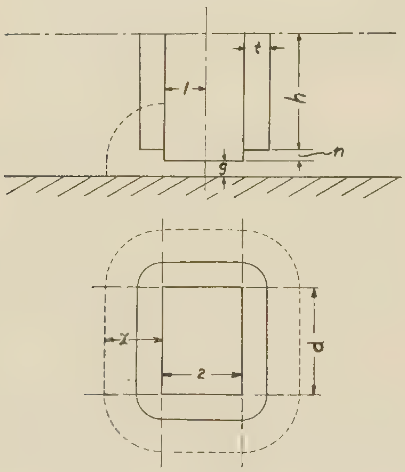

Fig. 6

If t is negligible in respect to h, these two equations become, respectively,

$$\% \phi_L' = \frac{g}{\pi d} (2d + 4 + 2h)$$

and $$\% \phi_L' = \frac{g}{2\pi} (8 + 2h)$$

2. Percentage leakage flux beyond the coil end is:

$$\% \phi_L'' = \frac{2g}{\pi d} \Big[2n + (d + 2) \log \Big(1 + \frac{n}{h} \Big) \Big]$$

If the core section is square, this becomes

$$\% \phi_L'' = \frac{g}{\pi} \Big[2n + 4 \log \Big(1 + \frac{n}{h} \Big) \Big]$$

3. Percentage fringing flux through the coil is:

$$\% \phi_F' = \frac{2g}{\pi d} \Big[\Big(h - B + \frac{4A}{\pi} \Big) + \Big(B - \frac{4A}{\pi} + \frac{2AB}{\pi h} - \frac{8A^2}{\pi^2 h} \Big) \log \Big(1 + \frac{\pi h}{2A} \Big) \Big]$$

where $$A = g + \frac{\pi}{2} n$$

and $$B = 2n + d + \pi + 2.$$

If the core section is square, this becomes

$$\% \phi_F' = \frac{g}{\pi} \Big[\Big(h - B + \frac{4A}{\pi} \Big) + \Big(B - \frac{4A}{\pi} + \frac{2AB}{\pi h} - \frac{8A^2}{\pi^2 h} \Big) \log \Big(1 + \frac{\pi h}{2A} \Big) \Big]$$

TABLE I

PERCENTAGE LEAKAGE AND FRINGING FLUXES FOR ROUND-CORE MAGNETS

	$h = 1$					
g	0.01			0.03		
n	0.1	0.5	1	0.1	0.5	1
$\% \phi_L$	0.012	0.019	0.027	0.035	0.057	0.08
$\% \phi_F$	0.06	0.07	0.077	0.14	0.167	0.19
g	0.06			0.1		
$\% \phi_L$	0.071	0.114	0.16	0.116	0.118	0.265
$\% \phi_F$	0.228	0.282	0.326	0.321	0.404	0.861
	$h = 3$					
g	0.01			0.03		
$\% \phi_L$	0.022	0.027	0.033	0.067	0.081	0.098
$\% \phi_F$	0.088	0.081	0.091	0.223	0.214	0.231
g	0.06			0.1		
$\% \phi_L$	0.134	0.163	0.197	0.263	0.284	0.342
$\% \phi_F$	0.402	0.375	0.408	0.62	0.558	0.612
	$h = 5$					
g	0.01			0.03		
$\% \phi_L$	0.031	0.035	0.04	0.093	0.107	0.122
$\% \phi_F$	0.11	0.107	0.112	0.291	0.279	0.294
g	0.06			0.1		
$\% \phi_L$	0.188	0.214	0.245	0.336	0.378	0.43
$\% \phi_F$	0.535	0.504	0.532	0.84	0.761	0.822

where $$A = g + \frac{\pi}{2} n$$

and $$B = \pi + 2n + 4.$$

4. Percentage fringing flux beyond the coil end is:

$$\% \phi_F'' = \frac{g}{\pi d} \Big[2n + \Big(B - \frac{4g}{\pi} \Big) \log \Big(1 + \frac{\pi n}{2g} \Big) \Big]$$

where $B = 2d + 2\pi + 4$.

If the core section is square, this reduces to

$$\% \phi_F' = \frac{g}{2\pi} \Big[2n + \Big(B - \frac{4g}{\pi} \Big) \log \Big(1 + \frac{\pi n}{2g} \Big) \Big]$$

Tables I and II give calculated results for round-

and square-cored magnets, respectively. Calculations are made covering a wide range of values as follows:

Gap length, g = 0.01, 0.03, 0.06, 0.1
Coil length, h = 1, 3, 5,
Height of coil above pole face, n = 0.1, 0.5, 1.
Thickness of coil, t = 1.

TABLE II
PERCENTAGE LEAKAGE AND FRINGING FLUXES FOR SQUARE-CORE MAGNETS

	$h = 1$					
g	0.01			0.03		
n	0.1	0.5	1	0.1	0.5	1
% ϕ_L	0.011	0.017	0.024	0.031	0.051	0.071
% ϕ_F	0.104	0.119	0.128	0.236	0.281	0.315
g	0.06			0.1		
% ϕ_L	0.063	0.012	0.143	0.105	0.17	0.238
% ϕ_F	0.348	0.374	0.439	0.534	0.671	0.78
	$h = 3$					
g	0.01			0.03		
% ϕ_L	0.019	0.023	0.028	0.058	0.07	0.085
% ϕ_F	0.106	0.117	0.124	0.244	0.276	0.302
g	0.06			0.1		
% ϕ_L	0.115	0.14	0.17	0.192	0.233	0.282
% ϕ_F	0.36	0.383	0.414	0.551	0.651	0.738
	$h = 5$					
g	0.01			0.03		
% ϕ_L	0.025	0.029	0.033	0.075	0.086	0.099
% ϕ_F	0.144	0.154	0.158	0.493	0.385	0.404
g	0.06			0.1		
% ϕ_L	0.151	0.172	0.197	0.251	0.286	0.329
% ϕ_F	0.602	0.601	0.617	0.946	1.011	1.073

TABLE III

g		0.01			0.03		
Point		a	b	c	a	b	c
h	n						
1	0.1	1.072	1.064	1.038	1.175	1.151	1.077
1	0.5	1.089	1.081	1.067	1.224	1.202	1.159
1	1.	1.104	1.097	1.085	1.269	1.248	1.214
3	0.1	1.11	1.087	1.037	1.289	1.222	1.074
3	0.5	1.118	1.10	1.064	1.295	1.254	1.149
3	1.	1.124	1.111	1.080	1.329	1.289	1.198
5	0.1	1.141	1.106	1.037	1.385	1.276	1.074
5	0.5	1.142	1.115	1.063	1.386	1.302	1.147
5	1.	1.152	1.125	1.079	1.416	1.332	1.194
g		0.06			0.1		
1	0.1	1.298	1.249	1.112	1.437	1.355	1.142
1	0.5	1.395	1.350	1.267	1.592	1.519	1.384
1	1.	1.485	1.442	1.376	1.743	1.672	1.562
3	0.1	1.534	1.390	1.107	1.841	1.584	1.134
3	0.5	1.536	1.455	1.248	1.827	1.690	1.352
3	1.	1.604	1.524	1.345	1.939	1.806	1.510
5	0.1	1.723	1.489	1.106	2.175	1.762	1.132
5	0.5	1.718	1.549	1.244	2.139	1.847	1.345
5	1.	1.777	1.610	1.337	2.252	1.949	1.497

DETERMINATION OF FLUX AND FLUX DENSITY ALONG THE CORE

In the calculation of the magnetic circuit of a dynamo it is customary to make use of a leakage coefficient, such as 1.15, by which the flux entering the armature is multipled in order to account for the leakage flux which must also be provided by the field ampere-turns. This factor has lent itself admirably to the exigencies of dynamo design, but its use has, perhaps, more practical than theoretical justification. To apply such a factor to the design of a lifting magnet would give results that are far from correct. The flux in the core varies in amount throughout its length, with the result that saturation is reached at the point of maximum density at much lower excitation than would be the case if the entire core carried flux represented by the leakage factor.

The flux density in any section of the core may be

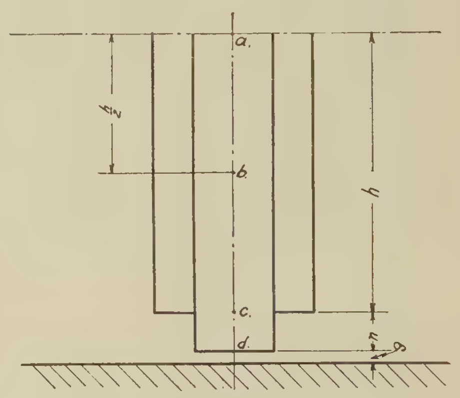

FIG. 8

obtained in the manner described: For example, let it be required to find the density at the point, b, in Fig. 8, the core section being round. By inspection it is seen that the core must, at this point, carry the fluxes ϕ_g, ϕ_L'', ϕ_F'' and those portions of ϕ_L' and ϕ_F' which leave the core below the plane of the point b.

We have equations for the first three fluxes. To obtain equations for the two remaining ones, it is necessary to develop equations (**1**) and (**6**), using appropriate integration limits for the point in question. For equation (**1**) these limits are $h/2$ and h, and for equation (**6**) they are 0 and $h/2$. Add together the fluxes mentioned in (**2**) as percentages of ϕ_g.

This process has been followed for points a, b, c, d, (Fig. 8) for round cores, and the results are given in Table III. The value for point, d, is always 1, as this is the flux ϕ_g in per cent of itself, that is $\dfrac{\phi_g}{\phi_g}$.

Both flux and density values may be obtained from Table III by multiplying any chosen value of gap flux or gap density by the factors in the table. For example, let the gap density chosen be 40,000 lines per sq. in. Then for a magnet having gap length, g = 0.01, coil

length, $h = 1$, distance from pole face to coil, $n = 0.1$, the factors for the points, a, b, c, are 1.072, 1.064 and 1.038 respectively; and the densities at these points are $1.072 \times 40{,}000 = 42{,}880$, for point, a, and 42,560 and 41,520 for b and c, respectively.

For these dimensions of the magnet it is seen that flux and density variation is slight; in fact, they are the dimensions which show least variation of all those given. When the gap is longer and the coil also longer, the variation is much more pronounced, and becomes increasingly important.

A similar set of values is given in Table IV for a

TABLE IV

g		0.01			0.03		
Point		a	b	c	a	b	c
h	n						
1	0.1	1.059	1.045	1.031	1.143	1.109	1.064
1	0.5	1.07	1.063	1.054	1.178	1.158	1.130
1	1.	1.081	1.077	1.069	1.210	1.199	1.175
3	0.1	1.076	1.056	1.030	1.197	1.137	1.062
3	0.5	1.082	1.070	1.051	1.215	1.179	1.121
3	1.	1.089	1.082	1.064	1.237	1.212	1.16
5	0.1	1.095	1.064	1.030	1.252	1.162	1.061
5	0.5	1.10	1.078	1.050	1.266	1.201	1.119
5	1.	1.106	1.088	1.063	1.284	1.232	1.156
g		0.06			0.1		
1	0.1	1.247	1.181	1.097	1.367	1.274	1.126
1	0.5	1.324	1.277	1.223	1.477	1.415	1.323
1	1.	1.382	1.359	1.311	1.587	1.551	1.470
3	0.1	1.352	1.238	1.092	1.535	1.355	1.118
3	0.5	1.390	1.320	1.204	1.60	1.484	1.292
3	1.	1.434	1.386	1.28	1.673	1.594	1.419
5	0.1	1.462	1.288	1.091	1.713	1.439	1.116
5	0.5	1.492	1.364	1.199	1.768	1.557	1.284
5	1.	1.527	1.424	1.272	1.828	1.658	1.405

TABLE V

Point	Coil excitation	Flux density	Percentage density
a	1.75	13,590	1.772
b	1.75	13,120	1.712
c	1.75	10,480	1.367
d	1.75	7,660	1.000
a	1.50	12,280	1.793
b	1.50	11,650	1.701
c	1.50	9,360	1.367
d	1.50	6,850	1.000
a	1.00	8,450	1.770
b	1.00	8,140	1.704
c	1.00	6,560	1.370
d	1.00	4,780	1.000
a	0.50	4,270	1.718
b	0.50	4,155	1.670
c	0.50	3,380	1.357
d	0.50	2,490	1.000

core of square section acting upon an armature of similar section, and of the form shown in Fig. 7. These values may be satisfactorily checked by experiment. In order to make this check, a core was built up of silicon steel laminations. The dimensions of this magnet, on the percentage basis, were as follows:

Gap length, $g = 0.1$
Coil length, $h = 5.0$
Distance from pole face to coil, $n = 1.0$
Thickness of coil, $t = 1.0$.

Table V gives the test values for four degrees of excitation of the core, the maximum density obtained being 13,590 gausses. Densities were obtained by the usual ballistic galvanometer method. It will be seen that over the range of densities employed there is no marked effect of density upon the percentage flux variation, which is evidence in support of the validity of the assumption, made at the outset, that the flux variations could be obtained in percentage of main flux in the gap, independent of density.

For comparison of test and calculated values we have the following results taken from Table IV and averaged from Table V.

Point	Observed (av.)	Calculated	Per cent variation
a	1.763	1.828	+0.035
b	1.697	1.658	−0.023
c	1.365	1.405	+0.030

Conclusions

The present paper is intended to cover only a portion of the work on magnetic-circuit calculations on which the authors are engaged. Magnetic-flux calculations are almost of necessity empirical, and the method here given is decidedly so.

No attempt is made to apply it to the complicated shapes that are usual in electrical machinery, that work being reserved for later consideration. Only such practical tests have been made as were deemed necessary to demonstrate that the calculated results were substantially correct.

The method here presented is of interest, therefore, largely as exhibiting flux variation and density variation in cores, as affected by air-gap length, position and shape of the exciting coil. By dealing with the subject on a percentage basis, we have the great advantage of being free from the actual dimensions of the magnetic circuit.

ELECTRICITY OUTPUT INCREASES

The Geological Survey of the Department of the Interior announces in its monthly statistical table on power production in the United States, that the average daily production of electricity in February of this year was 236,500,000 kw-hr., or one per cent more than the output for January.

The total power production for February is estimated at 6,858,423,000 kw-hr., as compared with 7,261,497,000 kw-hr. for January. Although the total output for February was nearly six per cent less than January, the statement showed that the average daily output for February was one per cent more than for January. "These are illustrations of misleading statistical data which would be obviated by the adoption of the proposed 13-month calendar" said the statement.

Abridgment of

The Reactances of Synchronous Machines

BY R. H. PARK[1] and B. L. ROBERTSON[1]

Associate, A. I. E. E. Associate, A. I. E. E.

Synopsis.—*Until somewhat recently, synchronous machine theory has been satisfied with a relatively few characteristic constants, or reactances, in terms of which the behavior of machines has been calculated. Present theory, however, requires many more coefficients. There are now generally recognized two values each of leakage, synchronous, and transient reactance, which correspond to the two symmetrical axes of magnetization of the armature current and which refer to balanced operation. Negative and zero phase-sequence reactances are also employed to determine operation under unbalanced conditions, and it is possible and desirable to distinguish other reactances. In view of the increasing complexity of the subject it is felt that a critical survey of it is in order and the object of the paper has been to provide that survey.*

The paper has been divided into two parts. Part I describes and treats of the subject with regard to those factors which are important to application or operating engineers, and to designers. In particular, the major types of reactances which include the synchronous, transient, and phase-sequence reactances, are discussed. These quantities are defined and their methods of test outlined. It appears necessary to consider a second type of transient reactance; namely sub-transient reactance. Both reactances may be determined from short-circuit oscillograms as illustrated in the paper. A table is included which gives the numerical range of reactances for the various types of synchronous machines.

Part II discusses the theoretical considerations, with a view to broadening and classifying existing conceptions of reactance. It includes the effect of external reactance on negative phase-sequence reactance and the variation in this latter quantity, depending upon whether current or voltage is impressed on the machine. An important aspect of the division of synchronous reactance into armature reaction and leakage reactance is discussed. Transient reactance is shown to be the difference between synchronous reactance and the ratio of the mutual reactance between armature and field and the total field reactance. Calculations are included to show that the short-circuit and open-circuit time constants are related to each other in a simple manner.

The appendixes cover the following subjects:

a. Application of the Principle of Superposition to Synchronous Machine Analysis.

b. Replacing the Effect of Induced Field Currents by Employing Transient Instead of Synchronous Reactances.

c. Significant Rotor Circuits in Addition to the Main Field Winding (which effect transient reactances).

d. The Negative Phase-Sequence Reactance of a Synchronous Machine with Negative Phase-Sequence Voltage Impressed.

e. Construction of Equivalent Circuits: Concept of Field Leakage Reactance.

f. Calculation of Total Field Reactance.

g. Relation of the Mutual Reactance Between Armature and Field to the No-Load Excitation Current.

h. Relation Between Three-Phase and Single-Phase Reactances.

i. Discussion of the System of Notation Used in the Paper.

j. Per-Unit Representation of Quantities.

* * * * *

In the analysis of system stability, and in the calculation of the effect of short-circuits, the factors of interest to operating engineers are those which relate to the behavior of the machine as viewed from the armature terminals. The most significant of these factors are the armature reactances of machines to normal frequency current having any distribution between phases, any power factor, and whether transient or sustained; also, in connection with transient components of current, their rates of decay, or decrements.

Types of Reactances. The major types of armature reactances, then, are to be distinguished according to:

A. Distribution; that is, the relative distribution of current between phases.

Any distribution of armature current may be expressed as the superposed sum of three symmetrical components:[3]

a. Balanced three-phase currents of normal phase rotation, or *positive phase-sequence.*

b. Balanced three-phase currents of reverse phase rotation, or *negative phase-sequence,* and

c. Balanced three-phase currents of equal time phase, or *zero phase-sequence.*

B. Method of application in time of positive phase-sequence currents.

Here it is desirable to distinguish between:

a. Steadily applied or sustained currents

b. Suddenly applied or transient currents

In the case of armature reactances, these differences are due to the transient currents induced in the rotor circuits when armature current is suddenly applied. If, as is generally so, there are closed circuits on the rotor in addition to the field winding, as, for example, an amortisseur, it is found that some of the currents in the rotor circuits may die away very rapidly. In order to distinguish between the affect of these currents and the affect of those which die away slowly, it is desirable to establish two (or more) transient reactances. The higher reactance, *i. e.*, the reactance which depends on currents that die away slowly, is then referred to as the *transient reactance* of the machine. The lower reactance may be referred to as the *sub-transient reactance* on account of its lower value.

C. Position of the rotor with respect to axis of magnetization of positive phase-sequence currents.

When the rotor is moving synchronously, the positive phase-sequence current can be resolved into two

1. Both of the Genl. Engg. Dept., General Electric Co., Schenectady, N. Y.

3. Reference (11).

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Feb. 13-17, 1928. Complete copies upon request.

components, one of which magnetizes in the axis of the poles, and the other in the inter-polar space. Accordingly, these components are referred to as *direct* and *quadrature*,[4] and the corresponding reactances are:

a. Direct, or
b. Quadrature.

Thus, to summarize, the types of armature reactance which have been considered so far are to be distinguished according to whether they are:

A. Positive, negative, or zero phase-sequence,
B. Sustained, transient, or sub-transient,
C. Direct or quadrature.

The determination of a suitable notation for these reactances should depend more upon present and future requirements than merely upon previous practise.

After careful consideration of the subject, it seemed that a consistent notation could be obtained by denoting the various types of reactance according to the method outlined below:

A. Distribution.
  Armature reactances
    Positive phase-sequence x_1, or no subscript
    Negative phase-sequence x_2
    Zero phase-sequence x_0

B. Application in time.
  Sustained—No special indication.
  Transient—One prime, *i. e.*, x'
  Sub-transient—Two primes, *i. e.*, x''

If it is desired to distinguish other degrees of transiency, additional primes may be added.

C. Position of rotor.
  Direct x_d
  Quadrature x_q.

The various armature reactances of the types discussed are then represented by the notation shown in Table I.

TABLE I
ARMATURE REACTANCES

x_d	Direct synchronous, positive phase-sequence.
x_q	Quadrature synchronous, positive phase-sequence.
x_d'	Direct transient, positive phase-sequence.
x_q'	Quadrature transient, positive phase-sequence.
x_d''	Direct sub-transient, positive phase-sequence.
x_q''	Quadrature sub-transient, positive phase-sequence.
x_2	Negative phase-sequence.
x_0	Zero phase-sequence.

Synchronous reactance: The problem of determining the relations between fundamental components of armature voltage and current during steady operation has been thoroughly analyzed by Blondel,[5] Arnold,[6] and Doherty and Nickle.[7] The accepted theory may be briefly summarized as follows:

First, the balanced three-phase system of armature currents is resolved into two component three-phase systems: one in which the current in each individual phase reaches a maximum at the instant that the axis of the field pole coincides with the axis of magnetization of the phase under consideration; and another in which the current in each individual phase reaches maximum at the instant the axis of magnetization is in line with the axis midway between poles, that is, one-quarter cycle later. The former is called the *direct* component because it produces direct component of armature reaction. The latter is the *quadrature* component.

Then coefficients are defined expressing the ratio of reactive component of voltage to armature current for each type of current. These coefficients are the *direct* and *quadrature* synchronous reactances of the machine.

These reactances may be expressed either in ohms, or as a ratio of their reactance in ohms to normal ohms, where normal ohms is the ratio of normal voltage and current. When so expressed, they are referred to as *per-unit reactances*.[8] Thus:

$$\text{Per-unit reactance} = \frac{\text{reactance in ohms}}{\text{normal ohms}}$$

$$\text{Normal ohms} = \frac{\text{normal line-to-neutral voltage}}{\text{normal line current}}$$

Consequently, *per-unit direct synchronous reactance* is defined as the *per-unit* fundamental component of reactive armature linkages, due to unit sustained direct component of armature current. Quadrature synchronous reactance is defined similarly. The resultant terminal voltage is then found by subtracting the reactance drop in each axis from the no-load terminal voltage corresponding to the existing field current, assuming no saturation. Hence, if the machine is dead short-circuited at normal voltage, the reciprocal of the per-unit sustained armature current is equal to the per-unit direct synchronous reactance.

Transient reactance. When a machine is subjected to a three-phase short circuit from an initial condition of no-load, the flux linkages in every rotor circuit must initially stay constant. But, since the armature current tends to demagnetize these circuits, it is necessary for the currents in them to increase, in order that the condition of constant flux linkages in each circuit may be fulfilled.

This increase in rotor m. m. f. is responsible for the familiar fact that the initial short-circuit current of a machine is greater than that obtained under sustained conditions, after the induced direct currents in the field and additional rotor circuits have died away. The resultant armature current is calculated in terms of the voltage before the short circuit, as the ratio of that voltage to a value of reactance referred to as the *transient* reactance of the machine.

More specifically, of course this reactance is the

4. A considerably broader conception of direct and quadrature quantities is developed in Part II.
5. Reference (13).
6. Reference (12).
7. Reference (8).

direct component of transient reactance, since it involves only reactive or direct axis component of current. Thus, direct transient reactance x_d' is

$$x_d' = \frac{e}{i}$$

where e is the voltage preceding short circuit and i is the symmetrical component of armature current just after the short circuit.

The exact interpretation of this definition would imply that the current i is to be measured as the value of the envelope of the wave of symmetrical component of current, as projected to the instant of short circuit. But, in machines with closed rotor circuits in addition to the field, this initial value may not satisfactorily represent the performance of the machine on account of the fact that the current induced in some or all of these additional circuits may die away very rapidly. It is desirable, therefore, to establish the conception of transient reactance proper, as the value of apparent transient reactance which applies to the current variation after the rapidly decaying components of current have died away. As shown in Fig. 4, it can be obtained by projecting the envelope of the current wave to the instant of short circuit, neglecting the first one or two peaks. Point (b) of Fig. 4 corresponds to the transient reactance proper. The reactance determined by the projected value of the envelope of the first few peaks of the current wave, point (a), is then referred to as the sub-transient reactance. In practise, the low value of this reactance may be due in part to saturation in the leakage paths.

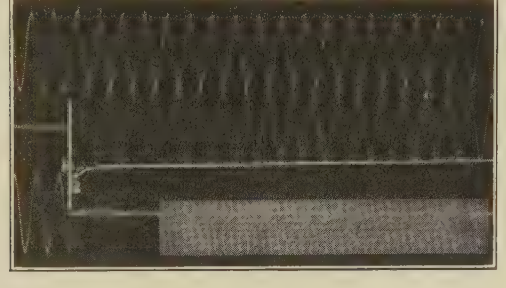

FIG. 4—DETERMINATION OF x_d' AND x_d'' BY METHOD OF PROJECTION

Negative phase-sequence reactance. In the case of a machine rotating synchronously, the application of fundamental negative phase-sequence current gives rise to negative phase-sequence fundamental and positive phase-sequence third harmonic voltages from line-to-line and from line-to-neutral. The per-unit negative phase-sequence reactance of a machine is thus equal to the per-unit fundamental phase voltage, or the per-unit line-to-line voltage, due to normal negative phase-sequence current supplied at the machine terminals.

15. See Appendix IV.

On the other hand, if the rotor is not moving exactly synchronously, the line-to-line voltages will not be purely fundamental, but, as is shown in Part II, they will contain slip frequency components. On this account, the direct determination of negative phase-sequence reactance by test is often inconvenient.

However, it can be determined very easily by static test since the negative phase-sequence reactance of a machine is very nearly equal to the average[15] of x_d'' and x_q'', *i. e.*,

$$x_2 = \frac{x_d'' + x_q''}{2}$$

Zero phase-sequence reactance. The application of fundamental zero phase-sequence current to a synchronous machine gives rise to pulsating third harmonic m. m. f. in the air-gap and end-windings, and to a slot flux the magnitude of which varies widely with the winding pitch. Thus, with other than full-pitch coils, the slot flux is diminished by the presence in the slots of coil sides carrying current in opposite directions. Zero phase-sequence slot reactance is thus very sensitive to pitch, and because of the fact just previously mentioned, is a minimum at $^2/_3$ pitch. The zero phase-sequence air-gap leakage also varies accordingly, and disappears at $^2/_3$ pitch, since in this case, there is no air-gap m. m. f. There is no armature reaction m. m. f. due to zero phase-sequence currents. Hence, zero phase-sequence reactance is very small, say from 15 to 60 per cent of the direct sub-transient reactance. The effect of the motion of the rotor is very small, and, consequently, there are no appreciable harmonic voltages. *Per-unit zero phase-sequence reactance* is defined as the per-unit phase voltage with normal zero phase-sequence current applied. While its definition implies a condition under which the rotor is moving at normal speed, if the rotor is stationary, the difference in test result is unappreciable.

DECREMENTS

Symmetrical component of current. The decrement curve of the transient armature current of a machine on short-circuit will be composed, in general, of several simple decrement terms or exponentials. That is, the current will be expressible as a series,

$$i = a + b\,\epsilon^{-\frac{t}{T_b}} + c\,\epsilon^{-\frac{t}{T_c}} + \ldots$$

where a is the sustained component of current, and b, c, etc., are the transient components of current with time-constants T_b, T_c, etc., respectively. In practise all but one of these time-constants will be small, *i. e.*, less than about one-twentieth sec., while for dead short circuits, the remaining time-constants will vary in large machines from about 0.5 to 2.5 sec.

Thus, a few cycles after the occurrence of a short circuit from an initial condition of no-load and voltage e, the armature current will be

$$i = e\left[\frac{1}{x_d} + \left(\frac{1}{x_d'} - \frac{1}{x_d}\right)\epsilon^{-\frac{t}{T_0'}}\right]$$

where T_0' is the short-circuit time-constant of the machine.

If the machine is operating at no-load and its field winding is short-circuited, the variation of armature voltage, shortly after the beginning of the transient, will follow a decrement having a time-constant T_0, which is larger than the short-circuit time-constant T_0'. These time-constants are related by the simple expression

$$T_0' = \frac{x_d'}{x_d} T_0.$$

As it happens that the open-circuit time-constant of most large machines is about 5 sec., the above relation provides an easy means of determining T_0' when the other three quantities are known. The time-constant T for a short circuit through an external reactance x is then given as

$$T = \frac{x_d' + x}{x_d + x} T_0.$$

D-c. component. On dead short circuits, the time-constant of the d-c. component is

$$\tau = \frac{1}{2\,\pi\,f}\;\frac{x_2}{r} \text{ seconds}$$

while if the machine is short-circuited through an external reactance, x, the time-constant is

$$\tau = \frac{1}{2\,\pi\,f}\;\frac{x_2 + x}{r} \text{ seconds}$$

where r is the armature resistance as a per-unit quantity.

The time-constant on a single-phase short circuit is calculated as for the equivalent three-phase short circuit.

Range of magnitude of reactances and time-constants. The range of magnitude of the direct, negative, and zero phase-sequence reactances, and the open-circuit time-constants of various classes of synchronous machines is shown in Table IIA following.

The first figures in any group of three quantities indicate the lower limit, the second figures are the average, and the third figures, the upper limit. It is understood that they are not absolute values, but are representative of most machines. Where only two quantities are mentioned, the lower and upper limits are meant. If only one term is given, it is the average reactance.

TABLE IIA

	x_d	x_d'	x_d''	x_2	x_0*	T_0 (sec.)
Synchronous motors						
High-speed	0.65–0.80–0.90	0.15–0.25–0.35	0.10–0.18–0.25	0.11–0.19–0.25	0.02–0.15	2–4
Low-speed	0.80–1.1 –1.5	0.40–0.50–0.70	0.25–0.35–0.45	0.25–0.35–0.50	0.04–0.27	
Synchronous condensers	av. 1.60	0.40–0.50	0.25–0.30	0.25–0.32	0.04–0.10	5–7
Waterwheel generators	0.60–1.0 –1.25	0.20–0.35–0.45	0.15–0.22–0.35	0.25–0.45–0.60	0.02–0.21	3–6
Turbo alternators						
solid rotor	av. 1.15	0.15–0.25	0.08–0.15	0.08–0.13	0.01–0.08	4–7
Laminated rotor	av. 1.15	0.15–0.25	0.08–0.15	0.10–0.14	0.01–0.08	

*x_0 varies from about 15 per cent to 60 per cent of x_d'', depending upon winding pitch.

This also applies to the case of single-phase short circuits. Thus, on single-phase short circuits, the positive phase-sequence component of current is to be calculated as the current that would exist when an equivalent[16] three-phase short circuit is applied.

In the case of short circuits under load, the time-constants of the rotor circuits in the quadrature axis are also involved. Except for solid rotor turbo alternators, these are all so fast, however, as not to merit attention from an operating standpoint.

The case of turbo alternators is also complicated to some extent by the large amount of saturation which exists in the rotor leakage paths. The affect of saturation in such paths is not confined to turbo alternators only, but is encountered to some extent in short circuits of salient pole machines. Its effect does not, however, greatly modify the general conclusions stated.

16. The equivalent reactance of a line-to-line short circuit is the negative phase-sequence reactance viewed from the point of a short circuit, while for line-to-neutral short circuits, it is the sum of the negative and zero phase-sequence reactances. The negative and zero phase-sequence currents can be found of course, by applying the conditions which hold at any instant,—that for line-to-line faults, the positive and negative components of current are equal in the fault; and that for line-to-neutral faults, all three components are equal in the fault.

ELECTRIFICATION IN GREAT BRITAIN

Out of a total of 594 installations in Great Britain in 1925, only three had a production of over 200,000,000 kw-hr., with an average of 283,000,000. Only two central stations can be considered as superstations, and more than 300 stations have a yearly production of less than 5,000,000 kw-hr. With the exception of authorized enterprises and large industrial organizations which produce electricity for their own use, 60 per cent of the country may be considered as not having the benefits of electrification, according to British statistics. During 1922 to 1925 the established electrical districts had a production of 5,754,000,000 kw-hr. (without counting the production of large industries). The per capita production of Great Britain is approximately 140 kw-hr. Sectional plans have been completed by the Electricity Commission of Great Britain for an extensive electrification plan to be carried out in the near future.—*Commerce Reports.*

Abridgment of

Excitation Systems

Their Influence on Short Circuits and Maximum Power

BY R. E. DOHERTY*

Member, A. I. E. E.

Synopsis.*—Since 1920, when the general subject of excitation systems was reviewed at the White Sulphur Springs Convention, two important problems regarding these systems have arisen: One relates to the required excitation characteristics during system disturbances, and the other to the characteristics which are necessary in order to increase the maximum power above the steady state or static limit—i. e., in order to operate the synchronous machines under the condition of dynamic stability.*

With respect to the former problem, the advantages and disadvantages of quick response excitation are considered. Such excitation tends, of course, to hold up the voltage during system disturbances, and is thus advantageous. However, it also increases the short-circuit current which circuit breakers must interrupt. The general trend in installing such systems is therefore in the direction of requiring larger circuit breakers. Such an excitation system is justified in many cases, and, indeed, it is essential in some. The extent to which the quickness of response and the maximum value of the excitation voltage are carried, is a question which, at present, should be settled by the conditions of the particular case.

As to increasing power limits, results are given which are very promising with respect not only to long distance transmission, but also to power systems which have approached the power limit as determined by the condition of present normal operation. A new regulator, unique in its operating characteristic, has been developed which makes it possible to sustain stable operation under the condition of dynamic stability, thus increasing the maximum power by taking advantage of a heretofore unexploited range of operation of synchronous machines. Comparative test results are given for different types of regulators. The new regulator alone showed extraordinary gain, giving an increase of maximum power from a steady state (steady-field excitation) value of 110 kw., to a maximum of 415 kw., on a system comprising a synchronous generator supplying power directly to a synchronous motor. This shows the extent of improvement obtainable in the machines themselves.

With an artificial 500-mile straightaway transmission line between the machines, a maximum power (received at the motor) equal to 90 per cent of the "infinite bus" value was obtained. The infinite bus value was 61 kw., 55 kw. was obtained, 44 kw. being the steady state power limit.

The excitation system, as controlled by the new regulator, provides a component of excitation voltage which is at all instants equal to the i r drop in the field circuit during the necessary small oscillation under dynamic stability. The i r drop is therefore compensated, the characteristic of the regulator being to introduce the effect of negative resistance. And with zero effective field resistance, the maximum power corresponds to the condition of constant flux linkages—the power under that condition is greatly increased above the constant field current value. This condition is approached by the new regulator.

* * * * *

Summary and Interpretation of Conclusions

WHAT interpretation is to be placed on the foregoing discussion and facts? Should quick-response excitation systems be always used, and how "quick" should the response be? What element in the excitation system has made possible the large gains in maximum power reported in the paper? What is the significance of the gains regarding the future of power transmission?

Two predominating facts in the field of power transmission have changed the aspect of this subject, and have introduced two corresponding problems in excitation systems. The growing demand for increased reliability of service has required quicker response of excitation systems on the occasion of system disturbance, in order to reduce the voltage drop to a minimum. And the increase in the load per transmission circuit and in the specfic loading of synchronous machines has brought rather sharply to the fore the limit of maximum power, which formerly was encountered only infrequently.

Quick-response excitation is of distinct advantage in important power systems where the demand for increased reliability of service is pressing; and this, of course, includes many of them. The character of the excitation system—whether of moderately rapid voltage rate, or an extremely rapid rate together with a high "ceiling" voltage—is, to a large degree, a matter of economics. It is a question to be settled by the conditions of the particular case.

But the question involves the very important aspect of increased short-circuit current. The use of quick response excitation means, in general, larger switches. The general trend in this direction should be duly considered in the choice of an excitation system.

Radical increase in maximum power above the steady-state limit—*i. e.*, above the value of maximum power which has heretofore been the practical limit—has been obtained in test. This involves a state of operation which is fundamentally different in character from that of the usual present day power system. This state of operation is termed *dynamic* stability, as distinguished from the condition of steady state, or *static* stability.

The increase in maximum power has been made possible by a new and unique voltage regulator. The principle which distinguishes this regulator, designated

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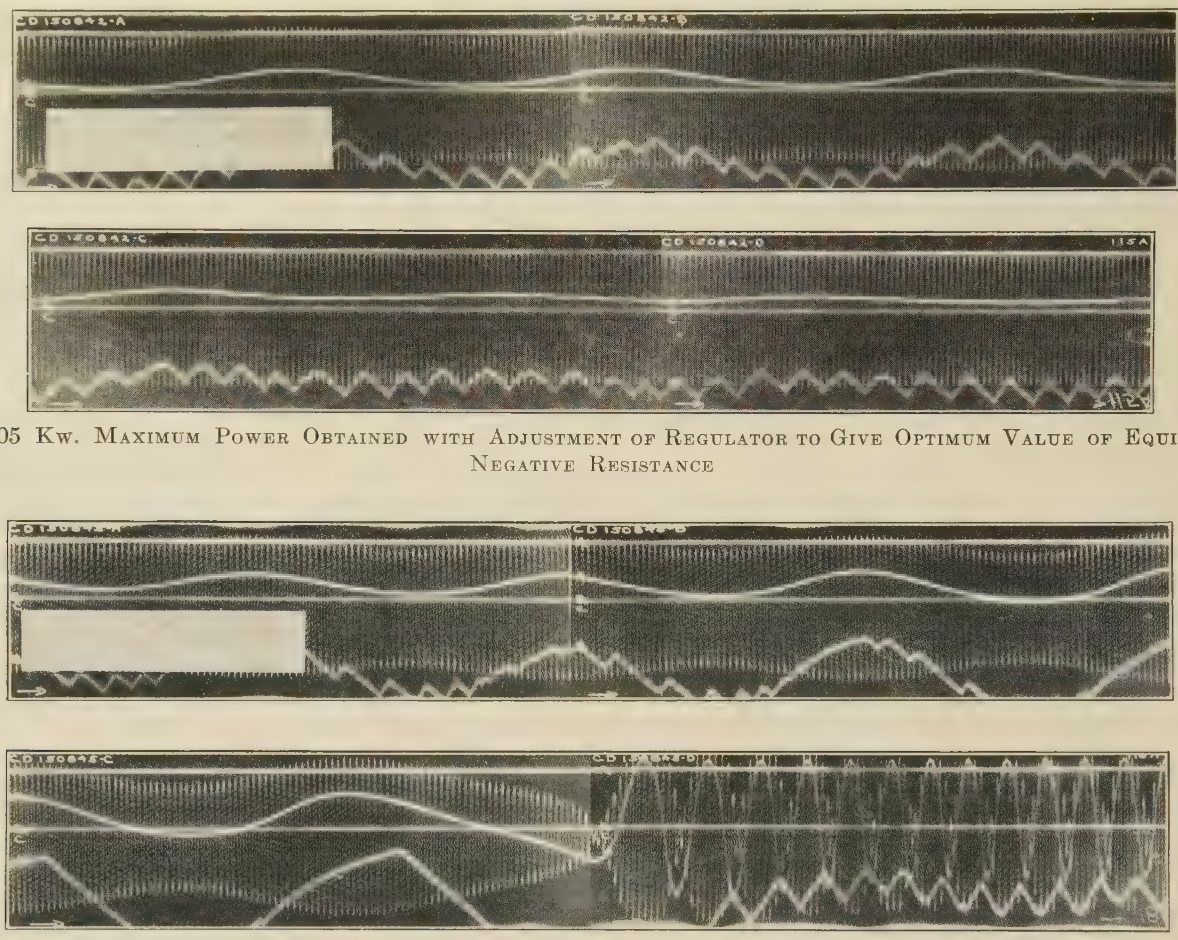
1. For all numerical references see Bibliography.

Presented at the A. I. E. E. Regional Meeting, St. Louis, Mo., March 7-9, 1928. Complete copies upon request.

n the paper by "type A," from all other existing types* is this: *for a given change in a-c. voltage, the new average exciter voltage for the new condition is reached at a continuous voltage rate equal to the actual total rate of the exciter. This is initiated promptly, and is true for all a-c. voltage changes, small as well as large.* The effect of the type A, or of type B which operates on the same principle, is to provide an equivalent negative resistance, thus giving a maximum power corresponding to constant flux linkages in the alternating field circuit. In other words, it gives a component of variable excitation voltage which is at all moments equal to the $i\,r$ drop, thus compensating for the resistance—and therefore for the armature reaction. (See Fig. 2.) This made it possible to obtain in test a maximum power of 415 kw. on a system, Fig. 3, for which the steady-state limit was 110 kw. See Figs. 2 and 4. This is a much greater maximum power than obtained with any other regulator.



(A) 405 Kw. Maximum Power Obtained with Adjustment of Regulator to Give Optimum Value of Equivalent Negative Resistance

(B) Cumulative Oscillation and Break-out at 370 Kw. Obtained with Regulator Adjustment to Give too Large Negative Resistance

Fig. 2—Oscillograms of Maximum Power with a Type A Regulator. Set-up Shown in Fig. 3. Steady State Power Limit, 110 Kw.

Curve A—True zero line displaced 50.5 mm. above reference line B_0. $T\,S$ field current 1 mm = 0.3 amperes (displaced axis B_0 = 15.15 amperes)
Curve B—Exciter armature voltage 1 mm. = 3.09 volts as measured from zero line A_0
Curve C—A. C. line voltage 1 mm. = 4.87 volts. P. T. Ratio = 20:1.

The effect of the type D regulator is equivalent to shunting the resistance of the field circuit with an inductance, thus introducing a phase displacement between the alternator field current and the excitation voltage. This is shown in Fig. 8. The maximum power is therefore less, being 190 kw., as compared with 415 kw., since the resistance cannot be completely compensated without introducing the effect of inductance. (See Fig. 7).

For relatively large changes in a-c. voltage—say of

*There are four principal voltage regulators with which comprehensive maximum power tests were made, including tests at different exciter voltage rates. Others were tested, but not so comprehensively. The four types are:

A. Original model of the regulator embodying the new principle. This will be referred to as type A.

B. New commercial form embodying, in the main, the characteristic features of the original model. This will be referred to as type B.

C. Older commercial form with d-c. coil, which will be designated as type C.

D. The usual commercial form without d-c. coil, which will be designated as type D.

the order of 10 per cent above, or 10 per cent below—the rate of the effective d-c. voltage approaches the total exciter rate with contacts closed; and for still large changes in a-c. voltage, as in the case of a short circuit, the contacts close and stay closed, thus giving the full exciter rate. This type is thus appropriate for a normal regulator below the steady-state limit, or in the case of short circuits; but it is not so suitable for quickly regulating for small voltage changes, as required under dynamic stability.

The type *C* regulator also delays action, on account of the dashpot, until large angular oscillations are set up; and its consequent effect is equivalent so inserting an inductance shunt around the resistance, as in the case of type *D*. Hence the maximum power is also lower and the hunting is more severe than in the case of types *A* and *B*.

All other commercial types, such as the "face plate regulator" and its derivatives, and the commutator type, are still more sluggish for small voltage changes.

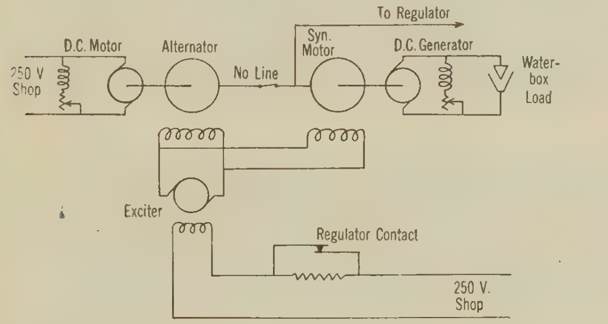


Fig. 3—Test Set-up Without Transmission Line

Machine Ratings
Alternator and motor TS-6-435-1200-4000/2300 volts
D-c. motor and generator MPC-6-300-1200-250/275 volts
Exciter MP-4-17-700-250 volt 68 amperes
Synchronous reactance (without saturation) of generator = 46 ohms
$W\ R^2$ of rotor (total) = 2880 lb-ft.^{2}

Some of these types are efficacious for quickly changing excitation on the occasion of short circuits, but they are not appropriate for sustained operation under dynamic stability. Thus, the difference between the large increases in maximum power which have been obtained by using the new regulator, type *A*, as reported in the paper, and the increases obtained by other regulators and by hand control, is explained by the fact that the new regulator functions according to an entirely different and novel characteristic, which was chosen with respect to the particular requirements of this problem.

Quick-response exciters are not essential to operation under dynamic stability. An increase of 100 per cent in power above the steady-state limit was obtained with the type *A* regulator controlling an exciter voltage rate of 24 volts sec. on a 250 volt exciter; and an increase of 275 per cent, with a rate of 142 volts/sec. No further increase was obtained when the exciter voltage rate was further increased, even to 2300 volts/sec. Thus quick-response excitation gave no more maximum power than the low rates of ordinary exciters. But it gave as much —*i. e.*, it did not impair the results, until the high rate of 3000 volts/sec. was reached. (Where an extremely high exciter voltage rate is used in connection with short circuits, this rate is applied only on the occasion of a short circuit. Normally it is not in the circuit.) Then instability occurred. It is thus concluded that quick-response excitation was not essential to the maximum gain in power limit obtained in the tests, because the gain was made without the use of such excitation.

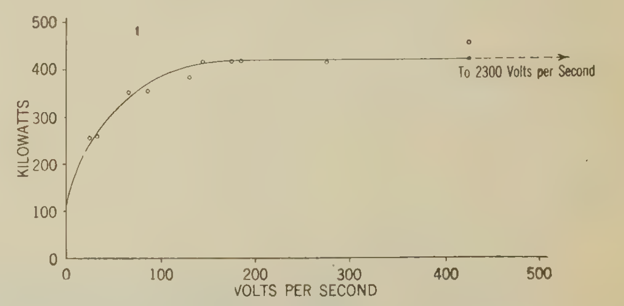


Fig. 4—Maximum Power as a Function of the Exciter Voltage Build-up Rate, for the Test Set-up of Fig. 3, Using Type A Regulator

But this does not mean that such an excitation system may not be desirable in a system normally operated under dynamic stability. It surely would be desirable, but for another reason—namely, to reduce the voltage drop during system disturbances, which is also the reason it is used on present systems normally operating below the steady-state limit.

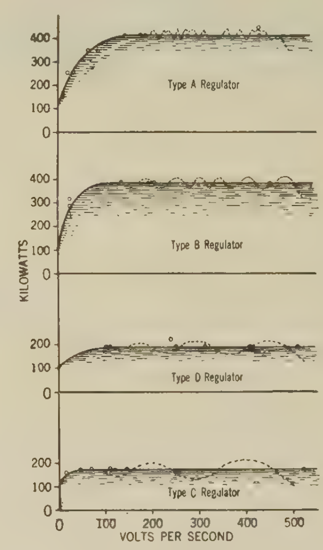


Fig. 7—The Solid Curves are the Same as Those Shown in Fig. 6

The shading is intended to indicate the intensity and range of hunting. Thus heavy shading indicates serious hunting, and no shading indicates practically stable operation. The dotted line, with time as abscissa, indicates the general character of the oscillation corresponding to imminent break-out

It should be added that the type *A* and type *B* regulators possess the required characteristics for controlling excitation both under dynamic stability and

under the condition of system disturbances such as short circuits. That is, they possess characteristics suitable for general application.

The most important aspect of the results is the possible influence on the future of power transmission. There are two phases of this which should be considered. One relates to the possible increase in the output of the synchronous machines for large central stations, or in special cases of industrial plants where momentary demands of power are greater than could be carried under steady-state operation, the other, to long distance transmission.

With respect to increasing the output of synchronous machines, the foremost limitations in design formerly were heating and voltage regulation. The latter was practically removed by the advent of the automatic voltage regulator, and the former has been progressively raised, principally by improvements in ventilation, and by the reduction of energy losses—*i. e.*, sources of heat. Consequently, the rated output has gradually approached, and has finally reached the immediate range of maximum power. Thus a new limitation is encountered. Although one can not draw general conclusions from factory tests, yet from both the test results and theoretical considerations, there appears to be no reason at this time why the limitation of maximum power could not be set much higher by the proper use of the new regulator, thus making possible a continued progress in higher specific loading of synchronous machines. The prospects are still more hopeful for satisfactory application in those special cases where considerable momentary overload is required from time to time. And even if normal operation were to be below the steady-state limit, less safety margin would be required, since the system would be capable of operating above the steady-state limit. That is, a new margin may thus be created by the regulator.

As to long distance transmission, the results appear very promising. With the new regulator, a maximum power equal to 90 per cent of the infinite bus value was obtained over an artificial 500 mi. straightaway line. The economic limitations in the power projects involving long transmission distances have been widely discussed in the literature. The situation has been faced that the maximum power which could be transmitted over very long distances was not sufficient to justify the necessary investment. The results of the present investigation are promising with respect to the possibility of removing some of those limitations and thus placing such projects on a much more attractive basis. Future developments will show whether such hopes are justified.

There is another factor which appears to be favorable in considering the application of the regulator on large machines. In such machines the mechanical inertia is relatively greater, and the electrical transients inherently longer than in the small machines used in this investigation. Thus, it would appear that the regulator would operate under still more favorable conditions when controlling the larger machines.

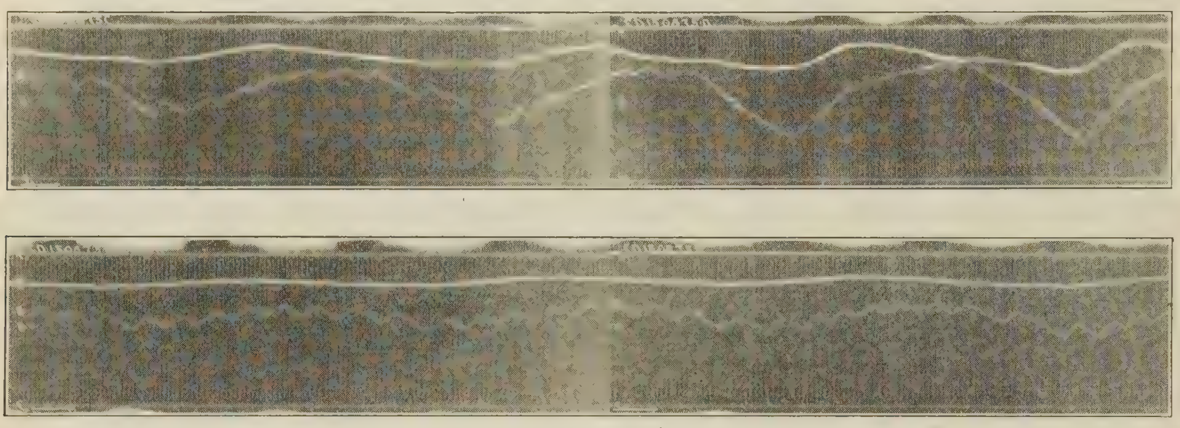


FIG. 8—OSCILLOGRAM OF MAXIMUM POWER TEST WITH A TYPE D REGULATOR ADJUSTED FOR OPTIMUM CONDITIONS. SET-UP SHOWN IN FIG. 3. STEADY STATE POWER LIMIT, 110 KW. 190 KW. MAXIMUM POWER OBTAINED

Curve A—Exciter armature voltage 1 mm. = 3.43 volts (as measured from zero line A_0
Curve B—A-c. line voltage 1 mm. = 5 volts. P. T. Ratio = 20:1
Curve C—*T S* field current 1 mm. = 0.135 amperes (true zero line displaced 0.09 mm. above reference line C_0)

ACKNOWLEDGMENTS

The author wishes to acknowledge the helpful suggestions of Messrs. C. A. Nickle and R. H. Park, and the assistance of Mr. C. C. Herskind in making the tests.

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Abridgment of

The Vibration of Transmission-Line Conductors

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Associate, A. I. E. E.

Synopsis.—*This paper is a continuation of a former one presented by the writer, in May, 1926.*

Records are given of vibration in actual transmission lines under widely varying conditions and with various conductor materials. These observations indicate the limiting values of wavelength frequency and amplitude of such vibrations encountered in service.

Laboratory experiments are described in which the observed conditions were artificially reproduced in a large conductor. The stresses adjacent to a point of support were studied with the aid of a microscope. The wave shape was plotted and the energy required to maintain vibration was recorded.

All conductor vibration breaks observed in practise have occurred at supports or badly made joints. The conclusion is reached that if the radius of curvature at the support can be maintained at least equal to that at the center of a loop, no breakage will occur.

Mathematical expressions are given for determinining the radius of curvature at the center of a loop, the bending moment at a support, and the necessary additional amount of conductor stiffness at the support to satisfy the desired condition.

There is described a simple form of stiffening device which even in a more crude form has been found effective in several cases of actual service.

IN the previous paper, the writer discussed the action of the wind on a suspended conductor and gave rules for determining the wavelength and frequency of the resulting vibrations.

Since the date of that paper, records have been kept of the wind action upon a large number of transmission lines equipped with different kinds of conductors and installed under various conditions.

Experimental apparatus was next installed at the Carnegie Institute of Technology at Pittsburgh by means of which certain of the data observed in the field could be reproduced in a particular conductor of large size.

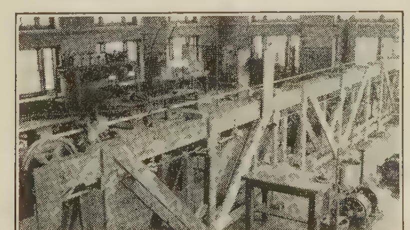

FIG. 1—FRAME FOR TESTING VIBRATION OF CONDUCTOR

This apparatus consisted of a heavy wooden frame provided with grooved pulleys at each end. Tension was maintained by turnbuckles and a dynamometer installed in the lower side of the conductor loop.

Vibrations were produced and maintained by a small motor operated from a storage battery, a counter shaft carrying a flywheel, a tachometer, and a crank disk, engaging with a light wooden connecting rod and guided plunger. This plunger was connected with the conductor by means of a small spiral tension spring. By varying the speed, one, two, three and four loops could be obtained.

In order to obtain definite conditions at the point of support, a heavy cast-iron block was bolted to the framework near one of the pulleys. This block held a split steel bushing bored out to fit the conductor accurately and tightly.

A high-power microscope was bolted to this block so that no relative motion existed between them. The microscope was then focused on the top of the conductor next to the end of the bushing. By means of an eyepiece micrometer, the maximum longitudinal motion of a point on the top strand of the conductor was observed.

The path of the observed point diminished longitudinally as the microscope was rotated from the top toward the side of the conductor, becoming more and

1. Aluminum Company of America, Pittsburgh, Pa.

Presented at the Regional Meeting of the A. I. E. E., St. Louis, Mo., March 7-9, 1928. Complete copies upon request.

more oblique and approaching a right angle with the longitudinal axis of the conductor on the horizontal transverse diameter. No effect of longitudinal vibratory impact could be discerned and the effects noted above are undoubtedly due to simple transverse bending in the vertical plane. The transverse motions of the conductor were carefully noted and plotted. The resulting curves are sine waves for all loops not adjacent to a support. The supports distort the wave, producing a bending action adjacent to it and a point of inflexion in the first half of the loop.

In all of the cases recorded, no breakage of strands has occurred except adjacent to a support or at a joint

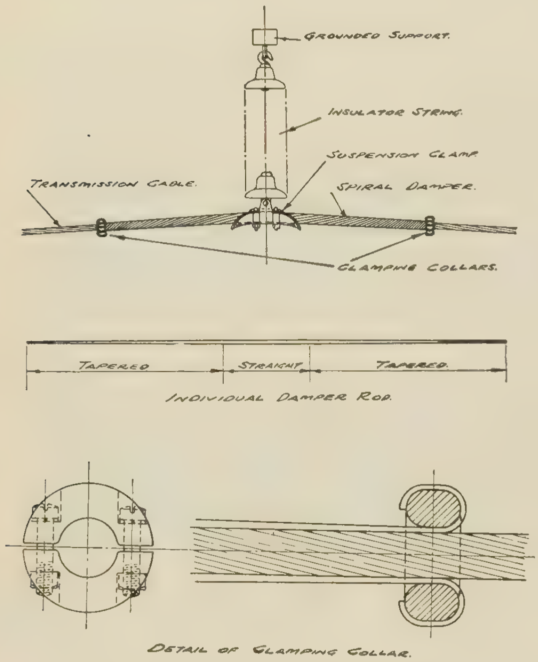

FIG. 2

which had been either poorly designed or applied. It is a logical conclusion that if means can be found to prevent any sharper bending of the conductor at a support or at a joint than occurs at the middle point of a loop, breakage due to vibration will be prevented.

Considerable thought and ingenuity have been expended upon the design of suspension clamps, but so far as the writer is aware, no logical method has previously been developed to determine the proper shape of the conductor seat. The support cannot be regarded as a simple node and it is difficult to provide effective means for permitting the wave to pass through the suspension clamp without bending the conductor. The reason for this is that it is impossible always to have a wave impulse leaving on one side of a support at the instant it is arriving on the other. This is evidenced by recorded cases of broken strands while the conductor rested on a sheave.

If the suspension clamp could be designed with a radius as large as that at the loop center, it would be effective, but it is difficult to do this within available limits of design. The angle of the conductor with the horizontal in a span of the greatest practicable length and sag at present in use, or contemplated, is about 23 deg. The summer to winter variation would be on the order of 2 or 3 deg., while the vibration angle is less than ½ deg. The correcting means must therefore be applied to the moving conductor.

A simple and practical method is to apply to the conductor a layer of cylindrical rods at the support. Preferably each rod tapers at each end, thereby enabling it to be twisted around the conductor and held at the ends. This gives maximum resistance to bending at the support and a tapering mass on each side to prevent sudden reflection of waves at its ends. This arrangement is illustrated in Fig. 2.

The above conclusions are based upon the observations and experiments described and also upon the following theory. Referring to Figs. 3 and 4, the letters have the following meanings:

L = Loop length = half wavelength
A = Amplitude of complete vibration
R = Radius of curvature at middle point of loop
Q = Angle with axis at node point of freely vibrating loop
P = Total tension in conductor in lb. (conductor not vibrating)
l = Arc length of loop
K = Moment producing bending at support
I = Moment of inertia of complete cable and damper at support
I_s = Moment of inertia of steel core of conductor
I_a = Moment of inertia of aluminum part of conductor
I_d = Moment of inertia of damper at support
M = Virtual modulus of elasticity of complete conductor and damper
M_s = Modulus of elasticity of steel
M_a = Modulus of elasticity of aluminum
M_d = Modulus of elasticity of damper material

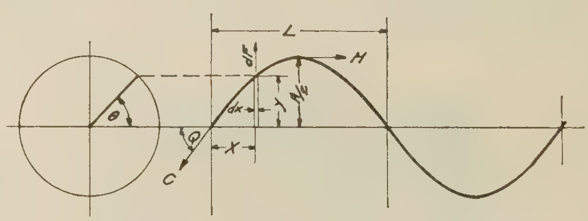

FIG. 3

$$y = \frac{A}{2} \sin \theta = \frac{A}{2} \sin \frac{\pi x}{L} \tag{1}$$

$$\tan Q = \frac{\pi A}{2 L} \text{ at origin when } x = 0 \tag{2}$$

$$d l = \left[1 + \left(\frac{dy}{dx} \right)^2 \right]^{1/2} dx \tag{3}$$

This expression can be integrated approximately as

follows:—

$$l = L\left(1 + \frac{1}{4}\tan^2 Q - \frac{3}{64}\tan^4 Q + \frac{5}{256}\tan^6 Q\right) \quad (4)$$

$$R = \frac{\left[1 + \left(\frac{dy}{dx}\right)^2\right]^{3/2}}{\frac{d^2 y}{dx^2}}$$

$$= \left(\frac{1}{\tan Q}\right)\left(\frac{L}{\pi}\right) \text{ when } x = \frac{L}{2} \quad (5)$$

When the loop is vibrating freely in the span away from a support, no bending occurs at O and the angle

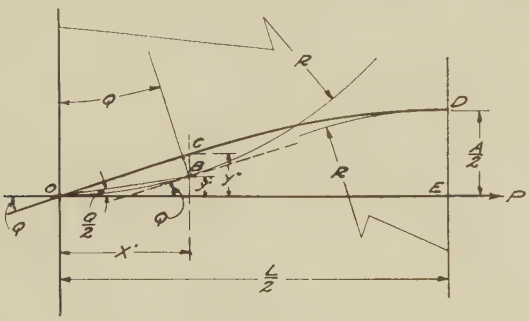

FIG. 4

Q is produced by the balanced motion of the adjoining loops. If a support occurs at O, the angle Q becomes zero at the left of O. The conductor at the right of O is bent into a curve, alternately concave upward and downward.

Although the angle Q is small, the bending produces very considerable fiber stresses which added to the direct tension in the cable has produced breakage.

In Fig. 4, a circle of radius R is drawn tangent to the axis of X at the origin O. At a point B, a tangent is drawn to this circle parallel to $O\,C$. This tangent makes an angle Q with the axis of X. The arc $O\,B$ subtends an angle at the center equal to Q and the angle

$B\,O\,E$ equals $\frac{Q}{2}$.

The arc length $O\,B$ is obtained as follows:

$$\text{Arc } O\,B = \frac{Q}{360}\,2\,\pi\,R$$

Chord $O\,B$ = arc $O\,B$, very nearly, since Q is small.

$$y' = O\,B \sin\frac{Q}{2} \quad (6)$$

Since Q is small, X may be taken equal to $O\,B$ and substituting this value of X in equation (1):

$$y'' = \frac{a}{2}\sin\frac{\pi X'}{L} \quad (7)$$

When the loop is freely vibrating, the tension in the wire produces no bending at O. When bending occurs at O, the resultant of the tension in the cable does not pass through O, and the bending moment is the product of the tension and the offset of the bend.

Under the conditions indicated in the figure, the bending moment at O is represented as follows:

$$K = P\,.\,B\,C = P\,(Y'' - Y'),\text{—very nearly.} \quad (8)$$

In order to satisfy these conditions, the following relation must obtain:

$$I\,M = R\,K \quad (9)$$

In order to satisfy this condition, I must usually be greater than the value corresponding to the wire itself. This value may be obtained by a reinforcing wrapping or damper, the proportions of which may be determined from the following expression.

$$R\,K = I\,M = I_s\,M_s + I_a\,M_a + I_d\,M_d \quad (10)$$

It is apparent from equation (8) that by assuming a series of values of R, and determining the corresponding values of K, the proper value of R' is obtained when the resistance to bending of the conductor, without damper, equals the bending moment thus produced. To illustrate this balanced condition, equation (10) may be written as follows:

$$R'\,K' = I_s\,M_s + I_a\,M_a \quad (11)$$

In the final analysis, the quantities to be determined are the fiber stresses, due to bending at the middle of the loop and immediately to the right of O.

If the strands are not restrained by friction, the fiber stress in each strand is due only to bending about its own neutral axis. Thus:

$$J_{Md} = \text{Max. Fiber Stress} = M_a\,\frac{d}{2\,R} \quad (12)$$

If the friction between the strands were increased by any means so that all relative slipping ceased, then the

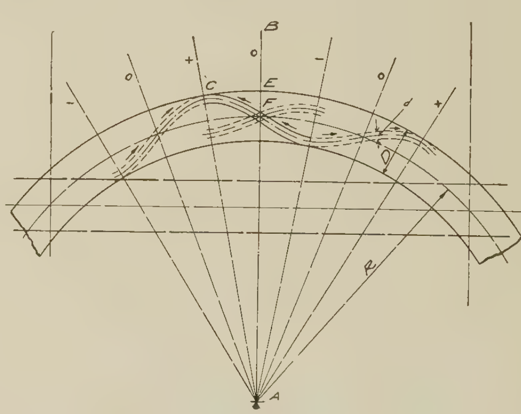

FIG. 5

maximum fiber stress would be expressed as follows:

$$J_{Md} = \text{Max. Fiber Stress} = M_a\,\frac{D}{2\,R} \quad (13)$$

The true value of the fiber stress is somewhere between these extremes and is close to that given by equation (12).

Referring to equation (11) the values of I_s and I_a will

TABLE I

Conductor—266,800 cir. mils A. C. S. R.	Diameter	0.633 in.	
	Wt. per Ft.	0.343 lb.	
Stranding:— 6 × 0.2108 in. Alum.	E.	0.2362	$(I_a\, M_a + I_s\, M_s)_d$ = 5480
	H_a	0.885	$(I_a\, M_a + I_s\, M_s)_D$ = 49160
7 × 0.0705 in. Steel	H_s	0.115	$(I_a\, M_a + I_s\, M_s + I_d\, M_d)_d$ = 162,900—With 7 × 0.475 in. Alum. Damper

Span (ft.)	Temp. (fah.)	P (lb.)	L (ft.)	A (1/32 in.)	F (C. P. S.)	Tan Q.	R (ft.)	J_{Md} (lb./sq. in.)	R_d' (ft.)	J_d' (lb./sq. in.)	R_D' (ft.)	J_D' (lb./sq. in.)	R_d'' (ft.)	J_d'' (lb./sq. in.)	J_d''' (lb./sq. in.)
1020	54	2260	4.0	4.	30.0	0.004090	311	254	46	1725	139	1710	288	274	619
1020	58	1825	9.5	4.	22.3	0.001723	1754	45	122	650	361	658	658	120	271
1020	70	1710	12.0	6.	17.2	0.002045	1867	42	103	768	315	754	572	138	312
1020	70	1710	14.0	10.	12.2	0.002921	1525	52	70	1130	212	1120	413	192	441
1020	70	1710	4.0	2.	45.0	0.002045	622	127	106	747	327	721	766	103	233
920	18	2370	20.0	6.	13.6	0.001228	5183	15	146	542	442	548	800	99	223
920	28	2270	8.8	4.	26.0	0.001859	1507	52	103	772	296	802	550	144	324
920	37	2135	10.0	6.	22.0	0.002454	1296	61	78	1015	231	1028	433	182	412
920	42	2005	4.2	1.	52.0	0.000974	1372	58	195	405	629	377	1283	62	139
920	48	1850	6.0	5.	35.0	0.003410	560	141	58	1355	179	1325	334	237	535
920	59	1840	8.5	3.	28.0	0.001444	1873	42	145	547	425	559	775	102	230
1020	−20	2720	4.0	4.	30.0	0.004090	311	254	41	1935	128	1850	250	316	714
1020	−20	2720	14.0	10.	12.2	0.002921	1525	52	56	1416	173	1370	313	253	570

depend upon whether the neutral axis is taken at the center of the conductor or at the center of each strand. Similarly, the value of R' will depend upon this same condition. The rather interesting fact develops that the fiber stress in the undamped conductor at the support is practically the same no matter which of these assumptions is made. See Table I.

The column headed J_d' represents the fiber stress in the conductor at a support with neutral axis at center of each strand. J_d' is the corresponding value with axis at center of conductor. Throughout this list these values are practically equal.

Table I further illustrates the effect of a damper cage consisting of seven aluminum rods each 0.475-in. diameter. In this case the radius of curvature is represented by R_d'', the fiber stress in the aluminum part of the conductor is given by J_d'' and the stress in the damper rods by J'''.

In Table I the last two cases are hypothetical as regards loop length and amplitude for − 20 deg. fahr. All the others are observed.

The effect of the damper is not only to increase the radius of the bend at the support but also to reduce the amplitude, frequency, and loop length which still further reduces the fiber stress due to bending.

In conclusion, the fact remains that in none of the cases recorded does the total normal tension stress plus the bending stress in the aluminum part of the conductor reach the endurance limit values which have as yet been established by the usual laboratory methods. The inference is that the bending action at the support creates an unequal distribution of the stresses between the several strands alternately overloading some of them and relieving others. If this bending can be sufficiently restricted, the damaging results must disappear.

Dampers similar to the type described herein have been in operation in certain cases for about three years, without breakage of conductor strands, whereas before the application of the dampers, breakages had occurred within from two to three months after installation.

The problem has been approached in a different manner by G. H. Stockbridge, Engineer of Transmission, Southern California Edison Co. He has successfully suppressed vibrations by means of an ingenious device located in the span some distance from the support.

The writer is indebted for valuable assistance to Prof. William R. Work, and Mr. F. E. J. Litot, Carnegie Institute of Technology. Also to Messrs. L. W. Henry, M. E. Noyes, H. H. Rodee, L. H. Hemeter, L. D. Hutcheson, R. L. Templin, and G. W. Stickley, Aluminum Company of America.

RADIO EQUALIZATION PLAN STARTED

Under the equalization clause of the Radio Act which recently became a law, the Federal Radio Commission is attempting to develop a suitable plan.

An informal conference of radio engineers was held in the Department of Commerce on April 6, as a preliminary step in the development of this plan. A tentative draft of alternative plans was prepared by the Commission and submitted as the basis for discussion.

An aggregate of 340 full-time assignments for the hours of darkness was proposed as an alternative, with increase in number of stations made possible during the daytime and during the night time, with time divisions.

It is contemplated by engineers in a position to judge that a great deal of difficulty will be experienced under the new equalization provision.

Superexcitation on Synchronous Condensers

For Conowingo System

BY D. M. JONES[1]

Associate, A. I. E. E.

***Synopsis.**—This paper outlines superexcitation as it will be applied to the synchronous condensers purchased for Plymouth Meeting, the receiver substation of the 220-kv. Conowingo transmission lines. In it are discussed the design limits of the excitation equipment as chosen and the emergency condenser output expected from it, are evaluated.*

Synchronous Condensers as Stabilizers

In planning the delivery of the electrical output of the new Conowingo hydro plant on the Susquehanna River to the system of the Philadelphia Electric Company, the proposal was made that a certain nominal capacity of synchronous condensers be located at Plymouth Meeting Substation, the receiver end of the Conowingo 220-kv. transmission lines. The expressed basic intent of this proposed installation was not voltage regulation, but an increase in the power transporting capacity of the transmission lines during system disturbances.

The consummation of this intent required that these condensers, although operating normally at reduced output, should render the maximum practicable stabilizing action during system short circuits.

This stabilizing action of a synchronous condenser is based on its flywheel effect and its kv-a. output during such a disturbance. If the condenser is adjacent to the generating area, its $W R^2$ is in effect added to that of the generators and reduces the angular advance of their rotors directly following the short circuit. If it is adjacent to the load, the condenser will add its flywheel effect to that of the load and thus minimize the angular retardation of the rotor of the equivalent synchronous load. In both instances the action helps to keep generator and load together, and thus tends to raise the stability limits.

The kv-a. output of a synchronous condenser during a disturbance helps to hold up the system voltage and thereby increase the power carrying capacity of the network. This emergency kv-a. output in a given condenser varies with the reciprocal of the transient reactance and directly with the excitation applied to it.

$W R^2$ and emergency kv-a. output, in so far as regards transient reactance, depend for their magnitude, on the major design constants of the condenser, and tend, in general, to follow along together with variations in these factors. These considerations suggested the possibility of raising a condenser's stabilizing capacity by special design. An analysis of this possibility, however, with reference to a condenser of given rating showed that when losses were kept within an economic minimum, the readjustment of the design factors to give an enlarged $W R^2$ and kv-a. output under the emergency conditions resulted in producing a normal synchronous condenser of increased rating. It was evident, therefore, that the most economic method of obtaining a given $W R^2$ and inherent kv-a. output from a synchronous condenser would be to select a standard machine of sufficient capacity to meet the requirements.

A study of the emergency output of a condenser by the use of additional excitation, however, showed such possibilities at nominal cost increases that it was decided to use this method to the practicable limit.

Critical Period in System Stability. From general consideration of stability, it was felt that what happened during the first swinging apart of the machines on the system following a short circuit determined, in most cases, whether or not the system held together. As this swing would occur in about one-half a second, it was felt that the condensers should be arranged to attain their maximum output within this period.

Maximum Output of Synchronous Condenser. It was recognized throughout that the general limits set for the equipment would have to be a reasonable compromise between maximum condenser outputs and practical economic considerations. In this spirit, the fact that a normal exciter would safely commutate, as a maximum, about double full-load current, and that this degree of excitation was beginning to produce saturation in the condenser, was permitted to establish the emergency output of these machines. Thus, their maximum output was placed as that obtainable with double-rate field current, which of course was a long way inside their short-time heating limit.

Exciter Ceiling Voltage. A check on the design limitations of the main exciter showed that approximately 1000 volts was a reasonable commutation limit if costs were not unduly raised, and approximately 1000 volts thus became the maximum, or "ceiling," voltage of the exciter.

Time to Attain Exciter Ceiling Voltage. As the effect of condenser output on stability during disturbances was practically a matter of integrated, or average, kv-a. output during the period, it was evident that it was desirable to obtain the maximum area under the time-

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Presented at Regional Meeting of the A. I. E. E., District No. 2, Baltimore, Md., April 17-20, 1928.

output curve for given maximum value. It was therefore decided to try to attain the exciter ceiling voltage in approximately one-eighth of a second. This led to the use of low-resistance main exciter field windings, supplemented by a permanent block of series resistance, to definitely limit the exciter to 1000 volts, as this was less than the saturation limit.

Separate Excitation and Sub-Exciters. Separate excitation at approximately 250 volts for the fields of the main exciter was decided upon for the following reasons:

Its use in connection with the main exciter field connections met the established excitation requirements.

It would result in an excitation equipment readily controllable by hand when occasion required.

This arrangement would impose only nominal voltage on the regulator equipment. Finally, a main field voltage of 250 was a convenience in the design of the sub-exciter from the standpoint of commutation requirements.

Properly, it should be added that in the matter of simply attaining a given maximum voltage in a minimum time, a self-excited exciter would give very good results when the maximum voltage, as in this case, is considerably above the value of the separate excitation. This would be true even though the self-excited type were handicapped by starting from comparatively low excitation values.

Type of Exciter Connection. In designing an exciter to attain its ceiling voltage quickly following a short circuit, an unshunted series winding proved particularly helpful, as it tended to overcome the excessive exciter armature resistance drop and demagnetizing reaction incident to the induced rush of main field current in the synchronous condenser following the disturbance.

This connection was also included on the sub-exciter for its helpfulness, both during transient excitation conditions and during normal variations of excitation load.

Type of Exciter. The direct-connected exciter is so enviably simple, both electrically and mechanically, that it was evidently desirable to use this type if the reduced rotational speed as compared with a motor-generator set would not offer too serious a handicap in the time required for the exciter voltage to reach its ceiling. This was especially true in the light of the fact that both main and sub-exciter could be mounted overhung, one on each end of the main shaft of the synchronous condenser.

A specific check on these exciters, direct-connected at 600 rev. per min., and separately driven at 1200 rev. per min., showed but a four per cent handicap in rate of rise against the machine with the lower rotation speed, and direct-connected exciters were therefore chosen.

This contradiction of the often expressed direct relation between rev. per min. and rate of voltage rise in an exciter warrants the explanation that although this relation does hold approximately on small units, it does not on large ones.

Reference to Fig. 1, will show more clearly the general relationship between these factors and especially the fact that when exciter $\frac{\text{kw.}}{\text{rev. per min.}}$, which is proportional to volume, exceeds approximately four-tenths, the time constant becomes practically a fixed quantity on machines of normal design.

In applying the test to the main exciter in this equipment, it will be necessary to use a rating corresponding to its physical size instead of the nominal rating subsequently given.

Since this main exciter has an armature and commutator construction corresponding to that of a 750-volt machine, its physical rating at that voltage is

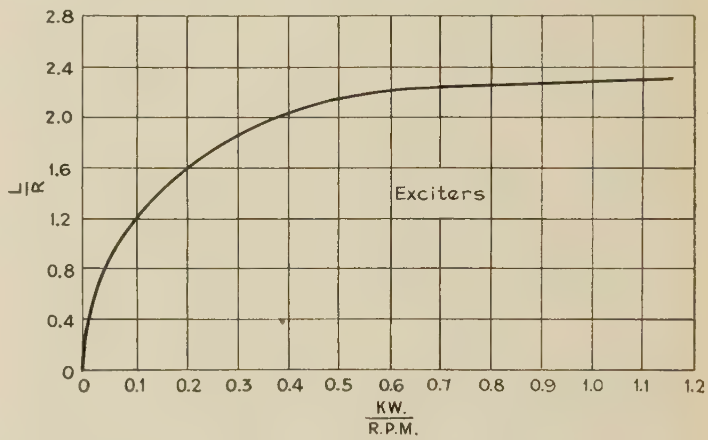

Fig. 1—Curve Indicating the Relation Between the Time Constant and the Speed and Rating of Exciters

495 kw. On this basis, the ratio of kw. to rev. per min. is approximately eight-tenths, which places this machine well on the flat section of the curve in Fig. 1,[2] thus agreeing with the specific check on the exciter build-up rates above mentioned.

Control Equipment

Acceptable control of excitation becomes more and more difficult as exciter voltage ceilings and rates of voltage rise become higher. In this case of superexcitation, therefore, the regulating problem is not negligible.

The control scheme consists of a vibrating voltage regulator with its relay contacts controlling the main exciter field, and a resistance in series with the field of sufficient magnitude to give satisfactory regulator operation at the minimum excitation required on the synchronous condensers.

2. This curve is taken from paper *Transmission System Power Limits*, by Nickle & Lawton, Trans. A. I. E. E., Vol. XLV., 1926, p. 1.

This series resistance is shunted totally by a master contactor and also progressively shunted in part by secondary contactors. These secondary contactors at the maximum are capable of reducing the excitation voltage to a value which will just sustain double normal field in the synchronous condensers.

In general, the vibrating regulator is of standard design. It is equipped with a three-phase torque motor instead of a single a-c. coil in order to provide proper response under all short-circuit conditions; and also with the recent improvements which materially raise the dynamic stability limits of synchronous machines under their control. In addition to these normal refinements, however, it does include a special depressed contact in conjunction with the normal pair of main floating contacts, so adjusted that it will close on voltage reductions incident to system short circuits. This contact closes the master contactor and thus

Required relation between rate of excitation rise and excitation ceiling voltage in order that load of synchronous condenser rated; ATI-12-30000 M-600 S-13800 Volt, when connected to an infinite bus, may rise from 10000 leading kv-a. to 55000 leading kv-a. in approx. ½ second. (0.05 sec. allowed for regulator to operate.)

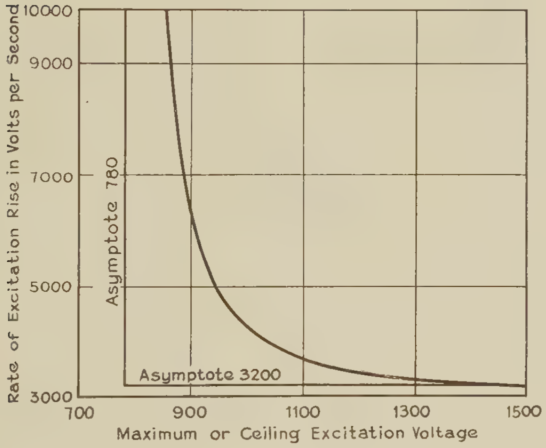

Fig. 2

shunts out all the control resistance in exciter main field circuit. This raises the excitation voltage to its maximum, but it is subsequently reduced to a value equivalent to double field amperes by a current relay in the synchronous condenser field, which opens the master contactor and inserts in the exciter field, circuit the resistance unshunted by the sectional contactors. Subsequent operation is directly under the control of the voltage regulator, supplemented, however, by current relays in the main exciter field, which control the sectional contactors so as to supply to the exciter field a voltage acceptable to the regulator under all conditions.

Resulting Ratings of Proposed Equipment

Eventually, the original proposal was translated into an order for definite equipment as listed below:

Three 30,000-kv-a. standard synchronous condensers, 13,800 volts, 600 rev. per min., 250 volts field, each equipped with:

A direct-connected main exciter, compound wound, with a nominal rating of 165 kw. at 250 volts, capable of commutating double full-load amperes at 1000 volts.

A direct-connected sub-exciter, compound wound, with a continuous rating of 40 kw., at 250 volts.

The maximum commutation requirement on the sub-exciter is the load resulting when its rated voltage is applied to main exciter field circuit under minimum resistance connection.

With this equipment as outlined, and terminal voltage held constant, it is expected that operating at 10,000-kv-a. output and normal voltage, a closing of the depressed regulator contact will raise the output to 55,000 kv-a. in approximately one-half second. These expectations are based on a performance in the excitation equipment, as outlined, and on a response in the synchronous condensers so computed as to include such factors, as will affect these machines.

Relation of Excitation Ceiling Voltage and Time of its Rise to Synchronous Machine Output

The interrelation of excitation ceiling voltage and the time required to acquire it in obtaining the expressed synchronous condenser output in approximately one-half second, is of interest.

Fig. 2 brings out the basic fact that pushing the ceiling voltage to an excessive value or time of rise to a minimum does not give corresponding improvement in the synchronous machine output. Thus, these factors should be utilized in magnitudes corresponding to commensurate or mid-curve values.

These values, however, are relative depending upon the requirements placed on the synchronous machine output. The greater the output increase desired in a given time, the greater will be the advisable ceiling voltages and the shorter will be the applicable time of rise.

For example, while an ordinary requirement for increases in output may limit the justifiable rate of exciter voltage rise to 400 or 600 volts per sec., and a correspondingly moderate exciter ceiling voltage, this case of super-output on a condenser makes it advisable to use superexcitation.

Reference to Fig. 3, giving the several values of output kv-a. plotted against time, produced by different combinations of an exciter ceiling voltage and an average rate of exciter voltage rise required to produce the fixed synchronous condenser output desired, shows a relatively narrow range of acceptable exciter build up rates.

Inspection of curves Nos. 2 to 5, Fig. 3, shows a constantly diminishing return in total kv-a. output, which confirms the decision to limit the rate of rise to the 6500 volts per sec. represented by the No. 2 curve.

Curve No. 5, Fig. 3, demonstrates that ordinary rates of exciter voltage rise are not applicable at all in

the accomplishment of the specified requirement, for, if the exciter build up is less than 3200 volts per sec., the desired condenser output cannot be obtained even with infinite maximum excitation.

Comparative Output of Synchronous Condensers with Different Excitation Systems

After the foregoing general discussion, a concrete comparison of different kv-a. outputs obtainable from the synchronous condenser in question with different types of excitation may be of interest. Fig. 4 was prepared to give this information on one of the 30,000-kv-a. condensers under consideration, operating under the expected normal condition of one-third rated load. The detailed data can be briefly abstracted as follows:

If the machine operating on an infinite bus were equipped with a normal exciter and voltage regulator and full excitation applied, the average increase in kv-a. output for the first half second, which is expressed by the area under the output curve, would amount to

Load-Time Curves of Synchronous Condenser rated ATI-12-30,000M-600S-13,800 Volts when connected to an infinite bus and the following excitations applied when the machine is carrying 10,000 leading kv-a. (0.05 seconds allowed for regulator to operate.)

Curve Number	Rate of Voltage Rise	Ceiling Voltage
1	∞	784
2	6400	900
3	5000	953
4	4000	1041
5	3200	∞

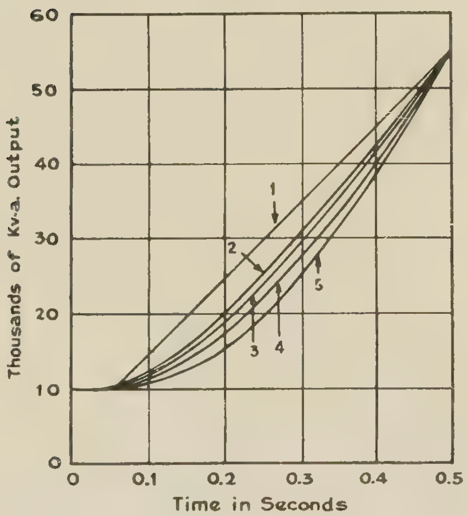

Fig. 3

approximately two and one-quarter per cent of the full rating of the condenser.

If under the same conditions, the nominal "quick response" type of excitation, with approximately 400 volts per sec. rise and normal exciter ceiling voltage were applied, the increase in output would become eight per cent.

If, again, the excitation, were raised at the rate of approximately 3000 volts per sec. to a maximum of 500 volts, the average output of the condenser would be raised 32 per cent of its full-load capacity; and finally, by using the superexcitation as contemplated, wherein the maximum condenser output is limited to the equivalent of double excitation, the increase becomes 64 per cent of the rating of the machine.

From this comparison it is evident that the degree of

Output-Time Curves of Synchronous Condenser rated ATI-12-30,000M-600-13800 Volts when connected to an infinite bus and the following excitations applied with the machine carrying 10,000 kv-a. leading (0.05 seconds allowed in each case for regulator to operate).
Curve 1- Standard excitation.
Curve 2- Normal "quick response" excitation.
Curve 3- Excitation with response and exciter ceiling voltage 50 per cent of super-excitation.
Curve 4- Super-Excitation.

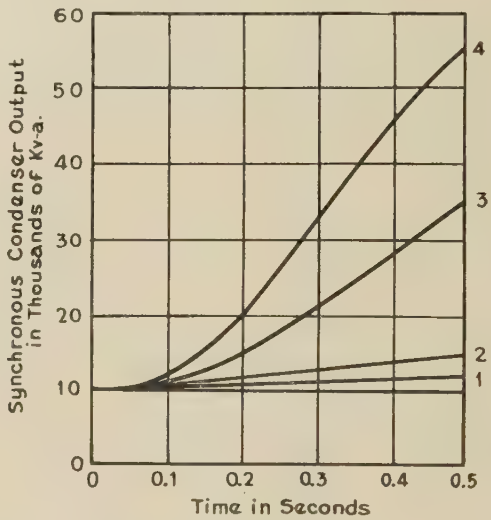

Fig. 4

superexcitation proposed does not exceed that which can be justified by the response.

Conclusions

In the light of the foregoing facts, this installation will place at least one new milestone beside the path of electrical development.

It will be the first use of superexcitation on a synchronous machine on any operating system.

The author wishes to express his appreciation of the considerable assistance given him by Messrs. R. H. Pork, O. A. Gustafson and F. R. Longley in the preparation of this paper.

The fifth Annual Convention of the American Oil Burner Association, held last month in Chicago, brought together 1500 delegates including many electrical men. Most of the principal oil burners have been approved by the Board of Underwriters, and there is a good prospect of cooperation between the oil heating industry and the electric light and power stations.

Abridgment of

A Thermal Method of Standardizing Dielectric Power Loss Measuring Equipment

J. A. SCOTT,[1] Associate, A. I. E. E. H. W. BOUSMAN[1] Associate, A. I. E. E. and R. R. BENEDICT[2] Associate, A. I. E. E.

Synopsis.—*After a brief review of the need for reference standards in dielectric power loss measurements at highvoltage and commercial power frequencies, this paper describes a thermal method for measuring dielectric power loss in cable, utilizing the sheath temperature rise associated with the flow of heat due to the power loss within the sheath. Sources of error are discussed briefly and results are given in comparison with measurements of dielectric power loss by the reflecting astatic electrodynamometer wattmeter, using an air capacitor for phase-angle compensation.*

In connection with the investigation, certain possible errors in dynamometer measurements are noted, particularly the effect of humidity on power loss in the air capacitor.

General

FOR some years engineers interested in the measurement of dielectric power loss at high-voltage and commercial power frequencies, such as in paper insulated cable, have felt the need for suitable means by which such measurements could be standardized. It is considered that such a means of expressing dielectric power loss in terms of well established units may be found in an examination of the heat appearing in the dielectric under consideration. The methods that occur to one as promising are either (1) a flow calorimeter or (2) the comparison of surface temperature rise of two samples under similar conditions, one having dielectric power loss, the other, a source of heat easily measured with the desired accuracy, such as d-c. ohmic power loss in the conductor. When the temperature rises are equal, the dielectric power loss in the former is taken equal to the ohmic power loss in the latter. The symmetrical geometry of lead sheathed cable, and the ease of making measurements on a short section of a long cable, thus avoiding end effects, led to the adoption of the latter method, which will be known in this paper as "comparison of heating." Results of preliminary measurements by comparison of heating at about 35 kv. three-phase were presented by Mr. E. S. Lee in the discussion at the Symposium on Dielectrics and Power Factor Measurements held at the Niagara Falls Regional Meeting of the Institute in 1926. The present investigation extends this method to single-phase measurements at 90 kv., and introduces refinements in the apparatus and method.

It should be noted that our immediate interest in this work was the detection of any constant error in the dynamometer wattmeter equipment as used for the measurement of dielectric power loss in high-voltage cable. Due to that interest, several other phenomena not closely connected with the thermal measurement of dielectric power loss,—especially the fairly definite loss in the air capacitor at high relative humidity,—were examined and are reported here.

This paper is presented that others interested in dielectric power loss measurements at high voltage and commercial power frequencies may avail themselves of our experiences with this method as a means of checking dielectric power loss measuring equipment.

Description of Apparatus

Comparison of heating requires the measurement of the ohmic power loss in the conductor of one cable that produces nearly the same sheath temperature rise as that of a similar cable to which alternating voltage is applied across the insulation, the cables being under like conditions for heat flow to the surrounding medium. That is, two like cable samples with suitable terminals are required mounted in some medium that provides approximately constant ambient temperature and like conditions for heat flow from the two cables. Means must be provided for measurement of the small temperature difference between the two sheaths with the necessary accuracy. Actual temperature rises are not needed if the conditions of constant equal ambient temperature and thermal emissivities constant in time can be maintained. These conditions were maintained on two single-conductor cable samples to the degree shown in the complete paper. (See Fig. 1.)

Suitable means were provided for measuring impressed high voltage on one cable and d-c. ohmic power loss in the conductor of the other cable.

Two schemes of temperature measurements were used. Four sets of thermopiles, each consisting of 20 copper ideal junctions in series, ten ("hot" junctions embedded in the sheath of one cable and ten "cold" junctions in the other), were distributed along the measuring sections of the cables to permit reading temperature differences. The second scheme consisted of five resistance temperature detectors made of 10-mil (0.065-sq. mm.) enameled copper wire, wound in contact with the sheath of each cable and covered with a strip of 0.01-inch (0.25-mm.) horn fiber.

1. Both of General Engineering Laboratory, General Electric Co., Schenectady, N. Y.

2. Graduate Student, University of Wisconsin.

Presented at the Regional Meeting of the A. I. E. E., District No. 2, Baltimore, Md., April 17-20, 1928. Complete copies upon request.

Heat Flow

Two questions may well arise here concerning the necessity for approximately constant ambient temperature and the possibility of error due to axial flow of heat along the conductor. Constant ambient temperature is necessary because the dielectric power loss in paper insulated cables at a given voltage changes with temperature and because of the two cables, the one heated by dielectric loss will respond more rapidly to changes in ambient temperature than the one heated by copper loss. Fig. 2, showing temperature difference as a function of time between two cables having dielectric power loss in one very slightly less than the ohmic loss in the conductor of the other, illustrates this.

The possibility of error due to axial flow of heat along the conductor was shown to be negligible by an approximate analysis of steady state conditions.

Precision of Measurement

D-c. power input measurements, as such, call for no further comment. They were of the precision usually obtained with portable instruments and ordinary care.

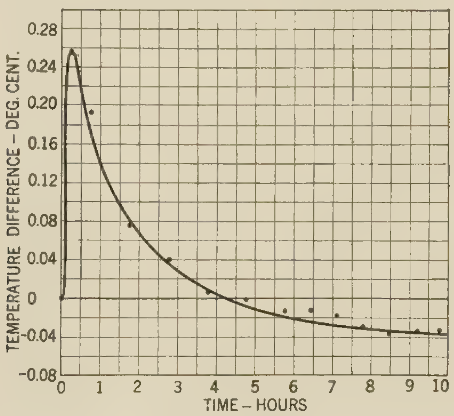

Fig. 2—Temperature Difference between Cable Sheaths as a Function of Time

Ordinate is temperature of cable sheath *A* minus temperature of cable sheath *B*, with dielectric power loss in cable *A* nearly equal to ohmic loss in conductor of cable *B*

It is necessary to note, however, that with our equipment, this power input could not be held as closely constant during a heat run as it could be read on the instruments. Momentary departures from the desired value of power input were as great as 1½ per cent. The same figure holds for departure from the desired value of voltage squared on the cable having dielectric loss. It is believed that the mean power over a short period was held to within one part in two hundred, although one per cent is reported here as a conservative value for probable error in holding constant power on each cable separately.

Cable charging current, although not entering into the determination of dielectric power loss, was measured using an electrodynamometer ammeter with an accuracy of one per cent. The same value of current at a given voltage, obtained from a series of determinations, was used in calculating all power factors at that voltage.

Temperature differences by thermopile were read by a galvanometer. The over-all sensitivity was 0.0015 deg. cent. per mm. deflection. Errors due to thermal e. m. fs. in the galvanometer and series resistance (used to secure proper damping) were eliminated by reversed readings. Connection to the thermopiles was made by means of copper braid clipped directly to the copper wire leads from the thermopiles. Here there is a source of possible thermal e. m. fs. not eliminated by reversed readings. This source of error was investigated and found small as compared with one mm. deflection.

In view of the fact that the resistance temperature detectors were read one at a time, it was necessary to follow a scheme of checking back, reading first a detector on cable "A", then one on cable "B", then back to "A" again, to avoid errors due to the small cyclic variations in ambient temperature previously mentioned. This variation amounted to about 0.03 deg. cent. at the detectors (0.2 deg. cent. in the air). The sensitivity was about the same as for thermopiles; *i. e.*, readings could be taken quite rapidly to 0.002 deg. cent. Incidentally, the labor of computation is considerably greater with resistance temperature detectors.

Sensitivity of this order, since it was easily obtained, was considered desirable even though it was a little better than the accuracy with which temperature rises could be held. That is, 0.002 deg. cent. represented about 0.001 watt per foot length of cable or not over one-fourth of one per cent of the loss in the cable. Control of loss was not quite so close,—say less than one per cent. It is believed that the cyclic variation of ambient temperature led to no constant errors, though it undoubtedly increased the deviation of individual readings from the mean.

Measurements of dielectric power loss on this cable were made with the dynamometer wattmeter measuring equipment under temperature conditions as nearly like those obtaining on comparison of heating as possible. This, together with the close agreement between various dynamometer wattmeter measurements made over a period of five weeks, is believed to eliminate the possibility of serious error due to change in dielectric power loss in the samples. The average of these measurements is recorded in Table III.

As a numerical value for error in any one measurement of dielectric power loss by comparison of heating, assume equal weights for one per cent error in holding d-c. power input constant, one per cent error in holding square of impressed voltage constant, and 1½ per cent error in power corresponding to one-half the cyclic variation of sheath temperature (0.03 deg. cent.).

$$[(0.01)^2 + (0.01)^2 + (0.015)^2]^{\frac{1}{2}} = 0.0206$$

or two per cent expected error in final dielectric power loss measurement. In this cable sample this is about two-thirds of 0.0001 power factor.

TABLE III

DIELECTRIC POWER LOSS IN CABLE BY COMPARISON OF HEATING, COMPARED WITH DYNAMOMETER WATTMETER MEASUREMENT

Ohmic loss in conductor watts per cm.	Sheath temperature difference θ, deg. cent.		Voltage applied to:		Dielectric power loss. Watts per cm.			*Power factor	
					By comparison of heating				
	by Th.	by R. T. D.	Cable	Kv.	Th.	R. T. D.	By dyn.	By comparison of heating	By dyn.
0.0155	0.096	0.117	B	75	0.0142	0.0142	0.0154	0.0031_3	0.0034_1
0.0144	−.008	0.021	A	75	0.0142	0.0143	0.0152	0.0031_4	0.0033_5
0.0182	−.041	−.002	A	82.5	0.0174	0.0177	0.0180	0.0031_5	0.0032_2
0.0182	0.068	0.104	B	82.5	0.0174	0.0171	0.0189	0.0031_0	0.0033_9
0.211	0.028	0.062	B	90	0.0209	0.0207	0.0226	0.0031_5	0.0034_2
0.211	−.003	0.028	A	90	0.0209	0.0211	0.0215	0.0031_8	0.0032_5

*Charging current 0.0605. 0.0667 and 0.0732 milliamperes per cm. at 75, 82.5 and 90 kv. respectively.

The error in a dynamometer wattmeter measurement, assuming correct phase-angle error compensation, is taken equal to 0.0002 power factor for samples of this size with the dynamometer wattmeter equipment used in this investigation. Thus, a difference between power factor calculated from dielectric power loss by comparison of heating and power factor from dynamometer wattmeter power measurement, greater than 0.0003 power factor, would call for explanation.

Experimental Results

Five runs with direct current in the conductor of each cable were made in order to establish the values of constants needed for the calculation of results, as described in the complete paper. These were followed by six runs (a "run" referring to the maintenance of a

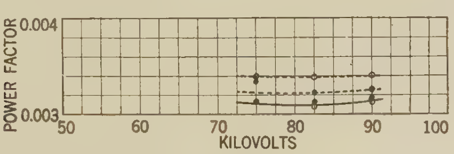

Fig. 4—Graphical Comparison of Power Factor Measurements

. Cable *A*
° Cable *B*

Solid line (————) represents power factor determined from dielectric power loss measurement by comparison of heating.

Broken line (-------) represents power factor from dynamometer wattmeter measurement of dielectric power loss

definite current in one cable and voltage on the other cable for the time, about 10 hr., required to reach approximate thermal equilibrium) the results of which are tabulated in Table III. In this table "th" refers to thermopile determinations. "R. T. D." to resistance temperature detector determination and "Dyn." to measurement of dielectric power loss by dynamometer wattmeter with air capacitor for compensation. Note that one run was made on each cable at each voltage as a further precaution against error or change in the constants referred to. To aid rapid analysis power factor results from this table are plotted as Fig. 4.

The two methods agree within nine per cent in any case, or within six per cent for average of all cases. This agreement is at about 0.003 power factor and represents a difference of 0.0002 power factor.

Application of Results

The comparison of heating measurements were made primarily as a precise check on the dynamometer wattmeter equipment for dielectric power loss measurement. To make the fullest possible use of this check and to avoid the necessity for frequent repetition of comparison of heating measurements, it became desirable that certain possible sources of error in the use of the air capacitor for phase-angle compensation of the dynamometer wattmeter be examined critically and the error reduced to a negligible amount. This work is discussed under two headings. (1) The effect of phase displacement between capacitor charging current and current through the dynamometer wattmeter current coils is under "Review of Compensated Dynamometer Wattmeter Measurement of Dielectric Power Loss." (2) The fairly definite power loss in the air capacitor at high relative humidity is under "Effect of Humidity on an Air Capacitor."

Review of Compensated Dynamometer Wattmeter Measurement of Dielectric Power Loss

It may be shown that the known or suspected constant errors in the dynamometer wattmeter equipment used in this investigation do not exceed 0.0001 power factor if there is no power loss in the air capacitor used for compensation.

Effect of Humidity on an Air Capacitor

Observation of the performance of several high-voltage air capacitors used for dielectric power loss measurement shows occasional conflicting results on damp summer days. These cases of suspected error, although infrequent, make all dielectric power loss measurements in terms of an air capacitor subject to doubt until the conditions associated with them can be stated. An examination of the technical literature fails to show that such doubtful readings have been ascribed to actual power loss in very humid air but in each such case humidity probably varied to a greater extent than did other conditions. Hence, it seemed well to investigate the effect of humidity on an air capacitor

used for phase-angle compensation of the dynamometer wattmeter for dielectric power loss measurement.

While the comparison of heating measurements were under way, such an air capacitor as has been described in detail elsewhere, was enclosed in a tight box equipped with means for controlling and measuring humidity. Humidity was increased by slowly introducing water vapor into a circulating air steam within the box or decreased by exposing calcium chloride in the box. Measurement was by wet- and dry-bulb thermometer in the air stream. In each case, time was allowed for the humidity of the air between the capacitor plates to assume a steady-state value.

The capacitor was used at various relative humidities and temperatures to compensate the dynamometer wattmeter for measurement of the apparent dielectric power loss and power factor of the cables previously standardized by comparison of heating. The power factor of either of these cables as measured repeatedly

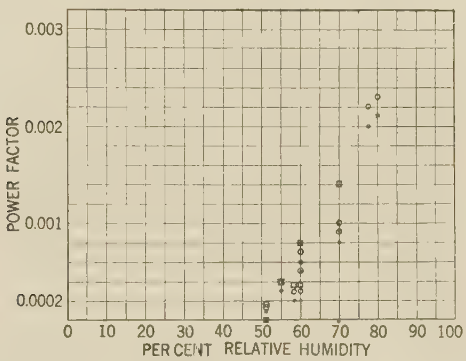

Fig. 7—Power Factor of Air Capacitor as a Function of Relative Humidity

. 50 kv. 60 cycles applied
° 70 kv. 60 cycles applied
□ 90 kv. 60 cycles applied
Air temperature 25 deg. cent.

by dynamometer wattmeter with the air in the capacitor dry was assumed constant. See Table III and Fig. 4. The difference between the assumed constant power factor and that measured when a given humidity and temperature existed in the air between the capacitor plates was taken as the "power factor" of the air capacitor at that humidity and temperature, indicating an actual power loss between the plates of the capacitor. Results of such measurements are shown plotted on Fig. 7. Considering the nature of the measurements involved, it is felt that these results are sufficiently consistent to warrent the conclusion that the capacitor is practically without loss below 50 per cent relative humidity and shows a very marked power loss above 50 per cent relative humidity, larger at greater humidities.

Incidentally, it may be recorded that at high relative humidities, say 70 per cent or 80 per cent, flashover of the capacitor may occur at very low values, as low as 0.7 normal flashover voltage.

No explanation is offered for the observed phenomena beyond a guess concerning charge carried on dust particles. A mixture of permanent gas and unsaturated water vapor was expected to behave as a permanent gas in an electric field. It is believed that the only difference between such a mixture and the dielectric in the capacitor is the probable presence of dust in the capacitor.

Conclusions

It is believed that dielectric power loss along two 10-ft. lengths of cable, as arranged for dielectric power loss measurement in the usual way, has been measured by a thermal method with the accuracy expected from the apparatus employed; *i. e.*, with a probable error not over two per cent. This measurement is at a power factor near 0.003. That the usual electrical measurement of dielectric power loss indicates slightly higher losses, the difference being of the order of magnitude of dynamometer wattmeter reading error, may be either accidental or associated with a small loss concentrated at the end of the measured length, in the 3/8-in. spacing between the measuring section and and the guard sections, indicated on the dynamometer wattmeter but missed by the thermal scheme. In either case it is considered that negligible loss in the air capacitor used with the dynamometer wattmeter is demonstrated, provided that care is taken to keep the relative humidity below 50 per cent in the capacitor. Present practise with this capacitor is the maintenance of relative humidity below 40 per cent.

The thermal method used seems sufficiently simple, accurate and independent of usual dielectric power loss measurements that its occasional use as a check in any laboratory making careful measurements of dielectric power loss is warranted.

RECENT INSTALLATION OF LARGE AIRWAY BEACONS

In addition to the new 1,000,000,000 candlepower revolving beacon which is soon to be installed in Chicago, a gift of Elmer A. Sperry, President of the Sperry Gyroscope Company, Brooklyn, N. Y., several other beacons of unusual size have recently been installed in various parts of the country. Within the past month a new airplane beacon was erected on the roof of the St. George Hotel in Brooklyn. This has a rating of 480,000,000 candlepower and is said to be the largest beacon ever built for private use.

Two revolving beacons now being erected in California by the Standard Oil Company for the guidance of West Coast fliers are said to develop 10,000,000 candlepower each. One will be placed on top of Mount Diablo, twenty-five miles southeast of San Francisco, at an altitude of nearly 4000 feet, and will be visible from points within a radius of 100 miles. The other is to be located among the Merced Hills in Los Angeles basin, just north of Montebello. These two installations will be similar—*Transactions I. E. S.*

Abridgment of

Some Aspects of Pacific Coast Interconnections

BY P. M. DOWNING[1]

Member, A. I. E. E.

Synopsis.—*This paper tells in general of the reasons for, and the advantages of, interconnection between power supply systems. It enumerates five essential factors which must be considered in successful operation of interconnected systems; namely, (1) dependable communication; (2) centralized authority and control over operations; (3) location and isolation of trouble; (4) voltage regulation and control over the entire system; and (5) frequency control. A description is given of the interconnections along the entire Pacific Coast.*

* * * * *

INTERCONNECTION, as that term is used when applied to the electrical industry, means nothing more or less than the pooling of the production and distribution facilities supplying power within a given area. It differs from transmission in that interconnection implies the transfer of energy from one system or area having a surplus to another system or area having a shortage, whereas transmission implies the transfer of energy from the point of production over a considerable distance to the point of usage.

Electric service was once local in character but with the advent of higher voltages which made possible the transmission of power over greater distances communities which theretofore had been supplied from local generating plants found it to their advantage to interconnect with other adjoining systems as a most logical and common sense way of making a more beneficial use of existing facilities.

Interconnection does not imply necessarily capital consolidation of the power supply systems involved. There are many instances where two or more independent systems are operating very successfully under contracts or working agreements that permit of economies not possible under separate operation. Very often, however, all of the advantages to be had from the interconnection are not obtained under contractual arrangements, due to the lack of sufficient flexibility in the contracts or working agreements in effect. To obtain maximum economic and beneficial results from interconnection, control and management should be unified. If power is to be distributed under the most favorable conditions, there must be, more than anything else, local territorial monopoly. No state, however richly endowed with water power, coal, oil, or other fuel, can make maximum beneficial and economic use of its facilities without interconnection.

At various times, we hear of "giant power" and "superpower" systems. While, to the imagination of the lay mind, these fascinating phrases probably make a stronger appeal than does the more homely and commonplace expression "interconnection," aside from the generally accepted idea that giant power implies State or Federal ownership, they mean substantially the same as interconnection, and all tend to accomplish the same end.

Some of the more enthusiastic proponents of giant power have gone so far as to suggest that there should be high-voltage lines of large capacity connecting different power-producing and power-consuming areas within the radius of practical electrical transmission. This, in effect would produce a single pool of power into which all generating stations would deliver power, and out of which, all distributing systems, irrespective of ownership, would take delivery of such amount as they might need. From an idealistic standpoint, such an arrangement would probably be well nigh perfect; but from a practical and economic standpoint, the investment in transmission facilities would probably be so great that the purpose sought to be accomplished would be defeated.

Some of the more important advantages to be gained by the interconnection of two or more different power-supply systems are as follows:

1. Greater reliability of service and increased economies. In case of a shortage of power due to accidents to equipments, other similar equipment on the interconnected system can supply the shortage until repairs are made or other units put into service. Under normal conditions, the more efficient units can be operated, the less efficient being held in reserve and operated only in emergencies.

2. Increased diversity, thus reducing the power requirements of the combined systems, and by improving the load factor, reducing the capital investment in plant facilities.

3. Common use of reserve or spare capacity, further reducing the capital investment in plant.

4. In cases where the network is supplied with power from both steam and hydro sources, the hydro stations can be operated continuously at full load when water is available, creating a maximum beneficial use of water power with a minimum use of steam.

5. General availability of power over large areas, making it possible for factories to locate where raw material, labor, market conditons, etc., are most favorable. This is particularly important, as it permits

1. Vice-President Pacific Gas & Electric Co., San Francisco, Calif.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Feb. 13-17, 1928. Complete copies upon request.

manufacturing plants to locate in smaller towns and agricultural areas, and to use labor normally employed during certain seasons only. In this way, interconnection becomes an active force in the decentralization of population.

Although there are many arguments in favor of interconnection as a most logical means of effecting economies, the extent to which power systems can be advantageously interconnected has certain limitations beyond which there is no advantage in going.

Unfortunately, the wide-spead discussion of this subject which has taken place of recent years has given the public the impression that it would be practicable to interconnect all of the power systems in the country irrespective of the distances at which they might be separated, and by parallel operation and exchange of power, effect economies to a point where the cost of power to individual consumers might be reduced. Nothing could be further from the fact. In the light of our present knowledge of the art, the advantages of interconnection are regional in character and limited to a radius of 300 to 400 mi.

In California, where perhaps more has been done in the way of unifying the ownership and operation of electric utilities than has been accomplished elsewhere, topography was an important factor in bringing the systems together. In the eastern part of the state, running north and south for hundreds of miles, are the Sierra Nevada Mountains, having hydro resources amounting to approximately 9,000,000 hp. In the extreme western part of the state lie the cities with markets for large blocks of electric power. Between the two are the wonderfully fertile agricultural valleys which of necessity had to be crossed by the transmission lines carrying power from the hydro plants in the mountains to the cities on the coast. The result of such a situation was the construction of a number of transmission lines converging toward the cities as a common point of delivery. Later, by a natural process of consolidation, various systems were united into larger units which were in turn interconnected, forming a network of lines which permitted of a ready exchange of power between areas supplied from a system under a single ownership and management or among several systems under separate ownerships and managements.

The power houses and transmission lines in California can all be interconnected to form a single network covering the entire state. Ordinarily there are three major connected groups. The first includes the California-Oregon Power Company, Pacific Gas and Electric Company, Snow Mountain Water and Power Company, City and County of San Francisco, Utica Mining Company, Coast Counties Gas and Electric Company, and the Truckee River Power Company.

The second, the Great Western Power Company of California, San Joaquin Light and Power Corporation, Merced Irrigation District, and the Feather River Power Company.

The third, the Southern California Edison Company, Southern Sierras Power Company, City of Pasadena, Bureau of Power and Light, City of Los Angeles, and the San Diego Consolidated Gas and Electric Company.

Along the routes of these transmission lines, running from the hydro plants on the western slopes of the mountains to the larger cities along or near the coast, there were many smaller cities, towns, and agricultural communities. Some of these were supplied with power from small isolated plants, while others were entirely without electric service. These small plants were inefficient and the opportunity to shut them down and obtain hydro power from transmission sources at less than it was costing to produce it locally was welcomed by all. At the same time the load thus obtained afforded a ready and quick revenue to the transmission systems. As a result of these mutual advantages, practically all of the isolated plants were abandoned very shortly after power was available from transmission sources. Eventually most of these small plants, together with the distributing systems, were taken over by the larger companies and became a part of a larger and more extensive network.

The agricultural areas were greatly benefited by the extension of these transmission lines. California is essentially an agricultural state, having a wet season and a dry one. Some indication of the extent to which electric power is being used for agricultural purposes may be obtained from the fact that the more than 35,000 irrigation pumping installations in this state represents a greater number than is to be found in all of the other states combined. When it is considered that the agricultural business is the least remunerative of any that is served by the supplying companies, it will be apparent at once that the rural communities have benefited greatly by the fortunate fact that nature has placed them between the source of power supply in the eastern part of the state and the principal market in the western part.

While California is generally recognized as having pioneered the long distance transmission of power, pointing out the advantages of maintaining interconnections between systems supplying adjacent territory, the field of interconnection has not been limited to this state. It has been extended until it now includes Oregon, Washington, Nevada, Idaho and British Columbia. Physical connections between systems operating in these various states are maintained and if found desirable, they could all be connected into a common network. As a practical measure however, this has never been attempted. The most extensive interconnection continuously in operation is that between the California-Oregon Power Company, supplying the central and southern parts of Oregon and the northern part of California, the Pacific Gas and Electric Company, supplying the northern and central parts of California, and the Truckee River Power Company, supplying the western part of Nevada. Involved in

this interconnection are 4760 mi. of high-voltage lines, 546,000 kw. of hydro generating capacity and 183,000 kw. of steam generating capacity.

Although the diversity of load found on most large interconnected systems tends to improve materially the load factor of the system, from a strictly economic standpoint, if best operating results are to be obtained it is still desirable to maintain a ratio between hydro and steam capacities that will call for base load being carried on hydro and peak and emergency loads on steam. The ideal relationship between these two sources of power supply will depend upon a number of elements, among which the chief are load factor, relative capital costs of steam and hydro installations, cost of fuel, etc. With a load that is continually growing, and the economic advantages that come from the construction of larger generating plants as compared with those of smaller capacity, the ideal allocation of load between hydro and steam to obtain maximum economy of operation is seldom, if ever, obtained.

From the standpoint of continuity of service, steam plants play a less important part today than they did a few years ago. Several factors have contributed toward bringing about this change. In the first place, as the number of hydro plants feeding into an interconnected network is increased, temporary cessations of operation of one or more generating stations whose output represents a comparatively small percentage of the total have but little effect on the general service of the system as a whole. A similar situation obtains in the case of transmission lines. So far as transmission is concerned, however, a much more important factor in improving service lies in the better quality and design of insulators that are now available and the better and more substantial physical construction used.

Some indication of the dependability of service from hydro sources may be had from the operating records of Pacific Gas and Electric Company for the year 1927. Climatic conditions in California during the past year were such as to afford an abundant water supply at all hydro plants. The steam plants located in the more important cities were floated on the line as a protection against interruptions to service that might occur in case of transmission line trouble. By operating in this manner, the load carried on steam was reduced to a minimum. With a peak load of 439,568 kw. and an energy output of 2,380,000,000 kw-hr., less than 0.9 per cent of it was produced by steam.

Some of the more essential features that must be given consideration in connection with the operation of interconnected systems are:

1. Dependable communication
2. Centralized authority and control over operations
3. Location and isolation of trouble
4. Voltage regulation and control over the entire network
5. Frequency control

One of the most important adjuncts to the successful operation of any large interconnected network of transmission lines is dependable communication. Under normal operating conditions where the distances are not too great, satisfactory communication can very readily be provided by carrying the communication circuits on the same supporting structures that carry the power circuits. Unfortunately, however, when trouble occurs on the power circuits, with this type of construction, the inductive disturbances to the communication circuits are generally sufficient to make them inoperative when they are needed most.

Much more dependable communication can be had over circuits independent of, and located a sufficient distance from, the power line to be out of range of inductive interferences. Most of the larger power systems in the West have communication systems of their own independent of the power systems, or lease from the telephone companies, circuits for their own exclusive use.

Recent developments in carrier-current radio equipment give promise of providing a cheaper and more dependable means of communication between different stations on a transmission network than any other now available. First, the carrier current is superimposed on the power lines at a frequency below that used by regular broadcasting stations, thus avoiding any interference of one with the other. Second, it can be installed on any voltage power line and is not materially influenced by switching, short circuits, or other transient disturbances on the power circuit. Third, in the case of long lines, the first cost of the installation is less than that of a metallic circuit. Fourth, it has all of the flexibility of a metallic system.

The most recent installation of this kind is that on the Pacific Gas and Electric Company's 220- and 110-kv. lines running between the hydro plants on Pit River and the load dispatcher's office in Oakland, a distance of approximately 240 mi. The service has been more dependable than that over an independent metallic circuit running between the two places.

The success attending the operation of large interconnected networks is due in a very large measure to the fact that authority and control over the details of operation are centralized in the load dispatcher. In emergencies, his authority is supreme. So important is this position that service from an interconnected network may be good or bad, depending upon whether the dispatching is handled well or otherwise. Allocation of load among the various generating substations and over the different lines in a way that will make a maximum beneficial use of the more efficient plants or equipment, conserve water or fuel, and at the same time prepare to meet any operating emergency that might arise, are some of the more important responsibilities of this position.

Localizing and isolating troubles that might be sufficiently serious to interrupt or impair service over a considerable area is another big problem that comes

up in connection with the successful operation of an interconnected network. At one time this was more or less a matter of guess work. Practically all switches were manually operated. Present day equipment has materially simplified this situation. Automatic overload, low-voltage, reverse current, time limit, reclosing, and other similar relays have almost entirely superseded manual operation in modern up-to-date installations.

As an interconnected network grows, and the amount of power delivered into it increases, the necessity for having dependable switches becomes of increasing importance. The construction of high-voltage switches has been materially improved during recent years, but there has been practically no change in the general design. Failure to keep pace with the development of other facilities used in connection with the production and transmission of high voltages has made them the weakest link in a power system.

The first attempt to build switches for operation at voltages as high as 60,000 was made in 1899 by the engineers of the Bay Counties Power Company, now a part of the Pacific Gas & Electric Company's system. The consolidation and interconnection of a number of smaller systems soon made it apparent that switching could no longer be done on the low voltage side of the transformers. The manufacturers had not yet developed switches for this voltage. To meet a situation precedent to satisfactory service from an interconnected network, it was necessary for the company to design and build its own high-voltage switches. The first attempts were necessarily crude.

Improvements in the design and manufacture of bushings have eliminated to a very considerable extent the inflammable material used in the original design, and present day switches are much more rugged and dependable than those of 25 years ago. Although these improvements have added to the mechanical and electrical efficiency of the equipment, they have also increased first cost to a point which, with the usual number of air switches for by-passing and cutting out the high-voltage oil switch equipment, in a modern generating plant represents an investment equal to 50 per cent of that in transformers.

No other piece of electrical equipment offers greater opportunity for improvement than high-voltage switches. The very satisfactory operation of the two 220,000-volt lines in California has proved beyond question the practicability of going to even higher voltages just so soon as the economics of the situation warrant. What the future may bring forth in the way of improvement in high-voltage switches remains to be seen. So far the vacuum-type switch has given more promise of relief than any other that has been proposed.

If electric utilities fulfil their obligations to serve the public, they must be able and willing to supply at proper rates any kind or character of load that may be offered them. Much of the load on a general power supply system will be of low power factor, and unless a consumer is penalized because of the low power factor of his load, or is offered inducement in some form by reduced rates or otherwise, to warrant his providing the necessary facilities for improving it, there will be a considerable amount of wattless current on the system that will have to be taken care of somewhere.

This may be carried on one or more generating stations to suit operating conveniences; or a much better plan, and one that becomes absolutely necessary as the length and voltage of the transmission lines increase, is to install synchronous condensers at or near the distribution centers of the system. The number and capacity of such installations will depend on the voltage of the system, the load characteristics, the permissible variation in voltage, etc.; but whatever capacity may be necessary to give proper service under normal operating conditions, if satisfactory service is to be given under abnormal conditions, it is very desirable to have a reasonable margin of spare capacity to maintain adequate service in emergencies.

Condenser installations may be fully justified not only as a most satisfactory means of improving voltage regulation but also for their tremendous economic value, since by improving the power factor, the amount of power that can be carried over a given line is materially increased.

Speed control on an interconnected system is a comparatively simple matter. Irrespective of the number, size, or location, of generating stations, one station does the governing. Ordinarily, the station near the load center, where a sufficient governing margin can be maintained at minimum cost, is selected. Where a hydro plant does the governing, it is desirable that one having sufficient forebay capacity to supply the varying drafts necessary to meet load fluctuations be selected. Where the network is supplied from both hydro and steam sources, especially where the latter is operated as a standby or reserve source of power supply, there is but little, if any, economy in governing with steam. Maximum economy will be obtained by loading all hydro plants except the one doing the governing, thus reducing the steam load to a minimum and keeping only enough boilers hot to pick up the predetermined amount of load that is to be thus protected against interruptions in case of trouble.

On a reasonably large interconnected network of lines, carrying a highly diversified load, the instantaneous variations in load, or what is ordinarily called the governing margin, is comparatively small. In fact, it is not at all unusual during short-water periods to reduce this to practically zero and follow the gradual variations in load by hand control. On the system of Pacific Gas and Electric Company, with a peak of almost 440,000 kw-hr. supplied to an area larger than any other interconnected network in the West, the normal governing margin is between 1000 and 2000 kw.

Transatlantic Telephony—The Technical Problem

BY O. B. BLACKWELL[1]

Fellow, A. I. E. E.

IT is the author's wish to present a picture, necessarily very briefly sketched, of the physical makeup of the transoceanic telephone circuit, why it has been given its present form, and what further improvements are expected as a result of development work now under way.

The problem, in brief, is suggested as follows: A telephone system of some 18,000,000 stations in America, and distances of upwards of 3000 mi.; a telephone system of about 1,500,000 telephones in England and the possibilities already partly realized of wire extensions to the other European nations; 3000 mi. of ocean between these two systems.

The establishment of a connection across the ocean presented two problems. First, the problem of setting up the radio circuit between the United States and England; and second, the problem of making this radio circuit function as a link between these two widely extended telephone systems.

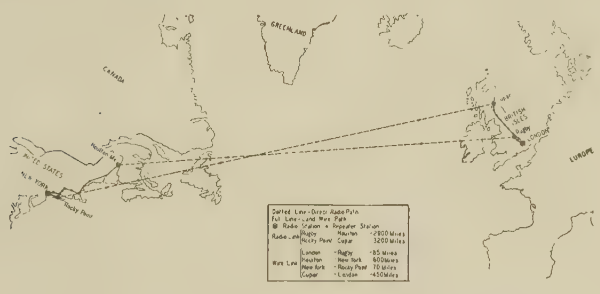

FIG. 1

Fig. 1 shows the geographical layout of the long-wave transoceanic circuit. The course pursued by the currents in a connection is as follows:

Voice currents originating at any substation in America are transmitted to New York City over the wire circuits in the usual way; thence, by wire to the sending station at Rocky Point, Long Island, where they are radiated into space. These waves are picked up at Cupar, Scotland, and transmitted by wires to London, from which point they go by the usual wire connections to the subscriber in England or on the continent.

The answering voice waves are transmitted from the European subscriber to London by wire and thence by wire to Rugby, England, at which point they are radiated into space. The waves are picked up at Houlton in the northern part of Maine and transmitted by wires to New York City, and thence by wires to the American subscriber.

It may be noted that the east- and westbound radio systems are entirely separate from one another. Also that the receiving points in both countries are carried as far north as convenient to Houlton, Maine, in this country, and in the British Isles, to Cupar, Scotland.

The radio and wire plant in Great Britain is owned and operated by the Post Office Department of the British Government.

As a supplement to the long waves, there is a short-wave circuit being formed which, so far, is only partially in use. During the severe static season of the summer of 1927, the short-wave circuit from the United States to London was employed as an emergency routing, extending from Deal Beach, N. J., to New Southgate, London.

In January, the British Post Office started sending on a return short-wave circuit from Rugby, England. This is now being received at Cliffwood, N. J., but is not yet ready for service.

Fig. 2B (necessarily on a logarithmic scale), approximates the frequency ranges covered by radio as it is now known. At the lower end are the long waves used in long distance telegraphy, extending down to nearly 10,000 cycles. At the upper end are the short waves, already more or less exploited, extending to about 10 meters; that is, 30,000,000 cycles.

It is interesting to note that one frequency range around 60,000, lying near the lower end of the scale, and another frequency range extending from about 10,000,000 to 20,000,000, near the upper end of the present scale, appear to be the most suitable for transoceanic transmission.

Fig. 2A has no bearing on the present subject. It is rather interesting, however, as it shows the whole gamut of frequencies with which we are familiar. Near its lower end this plot has a frequency of one cycle per 2000 years, which is supposed to characterize a particular comet. From this it proceeds through the frequencies corresponding to solar periodicities, through the frequencies used in commercial power systems, through the voice frequencies, the wire carrier, the radio frequencies, the longer heat waves, the visual light rays, ultra-violet rays, X-rays and to the very hard rays, sometimes called cosmic rays, with which Dr. Millikin's name is associated because of the investigations which he has carried out regarding them. This whole matter of frequency range and the relation of each part to

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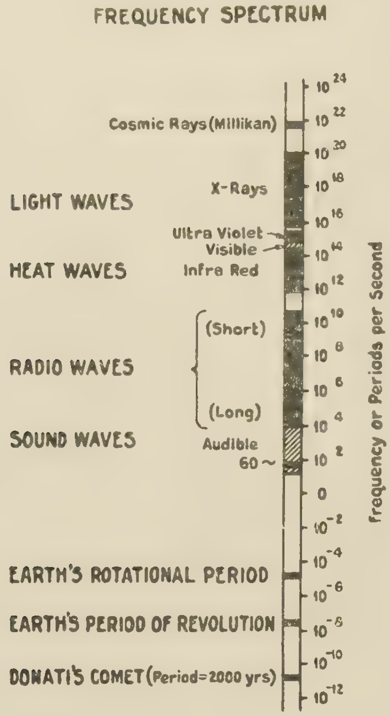
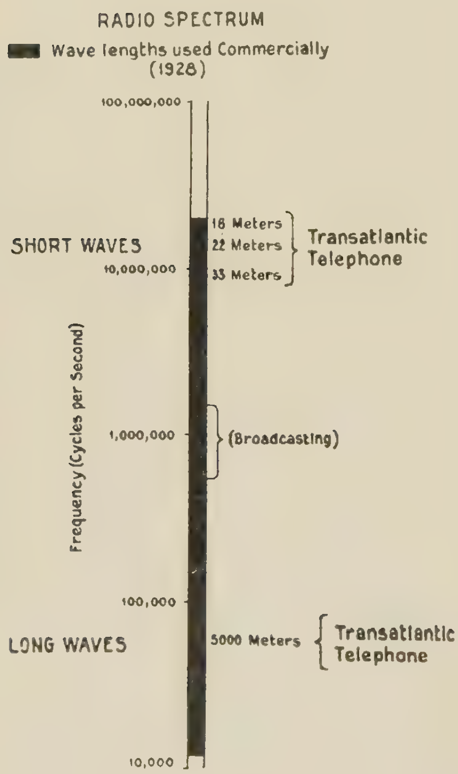
Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 13-17, 1928.

human needs is of the greatest significance and interest.

In considering how these long and short radio waves are handled in forming the transoceanic circuit, we shall look first at the transmitting stations and antennas; next, at what happens to these waves in space; and then, at the receiving antennas and stations.



A



B

Fig. 2

Assuming that the power is put into proper frequency form and radiated into space, the next question is, how does it fare in traversing the great distances before it reaches the receiving points. It can hardly be stated as a technical *problem*, since there is nothing the engineer can do to control it. He can find out, however, what nature does to such waves and try to arrange his transmitting, and particularly his receiving systems to meet the characteristics of the waves.

There appears to be nothing to show this space transmission unless possibly a picture of the world rotating in space such as we have seen adorning popular articles on radio. It might be suggested, however, by contrast with wire transmission.

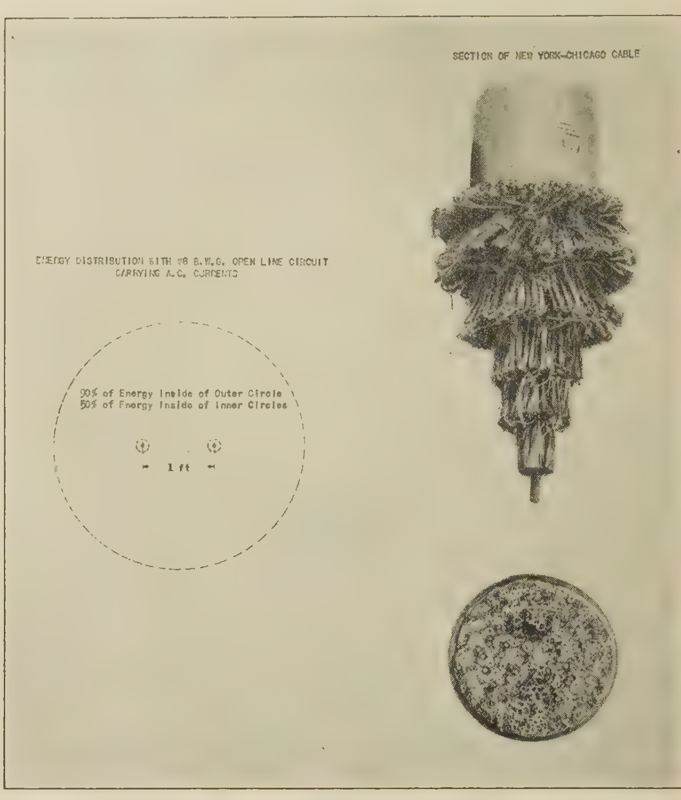


Fig. 3

Fig. 3A shows a cross-section of a pair of copper wires spaced a foot apart on a pole line, which is the standard telephone wire arrangement. On such a circuit, 90 per cent of the energy is transmitted inside of the outer dotted circle. Fig. 3B shows two views, (one a cross-section) of a typical telephone toll cable of a diameter somewhat under three inches. Practically all the energy for about 300 telephone circuits is transmitted inside this sheath.

While both the radio and the wire transmission involve similar electromagnetic waves, there could hardly be a greater contrast in the method of handling waves than that between the radio transmission considered in this paper and transmission employing such wire methods and spanning the comparable distance of, say from San Francisco to New York.

Recently, while visiting the short-wave receiving station in New Jersey, the author was shown oscillographs taken on radio telegraph transmission, in which each telegraph dot was followed about a tenth of a second later by what appeared to be an echo. The first transmission came some 3000 mi. from England, the second had gone in an opposite direction around the

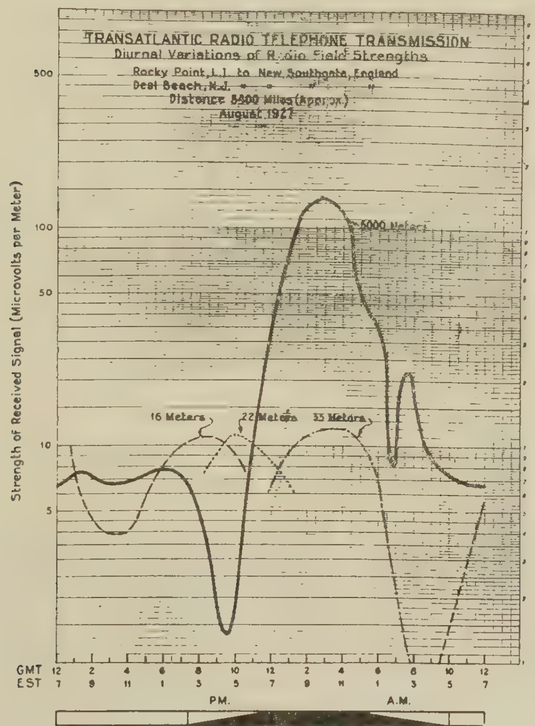


Fig. 4

world and had traveled some 22,000 mi. before reaching the same receiving point. In such long distance radio, then, there may be a situation in which each individual signal sets up oscillations,—perhaps measureable in space surrounding practically the whole earth.

Contrast this to the toll cable shown, which, as already noted, contains about 300 circuits. Such cable is used commercially for distances up to approximately 1500 mi., and is permissible for 3000-mi. distances, such as we are here considering. In this cable, each message is practically confined to a strip of space extending between the terminals of the cable and smaller around than a lead pencil. In the radio case, one has literally all outdoors, but there is little one can do to control it. In the cable case the channel is reduced to the most meager dimensions, but this space can pretty nearly be called our own, surrounded and shielded as it is by a sheath, and containing carefully balanced circuits. Such space is only occasionally penetrated by outside disturbances when some power friends set up unusually strong electrical fields in the immediate neighborhood. By loading, amplifiers, and equalization of various sorts, this meager space is guarded and controlled and rendered efficient and constant.

We are still somewhat in the dark as to how kind nature has been to us regarding short waves and what degree of reliability we can ultimately get from a circuit employing them. There is nothing yet in the picture, however, to suggest a reliability for either long or short waves approaching that of a cable circuit for similar distances.

A large amount of measurements has been made of the strength of the radio fields laid down in England from the long- and short-wave stations in America and similarly in America from the English stations. Along with such data is taken the amount of noise interference present at the receiving points. Fig. 4 shows data taken in this way. The curve which reaches the highest point shows for a typical summer's day the field strengths received on the long wave from America. The other curve shows the field strengths received on short waves employing three wavelengths—16, 22 and 33 meters—and taking for each time of day, the one of these which was best suited to the conditions.

On this typical day, all the wavelengths were operating well. It will be noted, however, that there are times when the long wave is low and some one of the three short waves is more effective, and other times when none of the three short waves are high but the long wave is effective. Furthermore, all of these waves vary a great deal, so that on certain days for hours shown operative on these curves, one or more might be entirely out of service. This chart indicates the tremendous advantage in employing a number of separate wavelengths varying widely in characteristics, and choosing at any one time that wavelength which is giving the best performance.

Having followed the radio transmission as the waves radiate into space and traverse space to the receiving end, we come to the matter of receiving stations.

So much for the question of the radio circuits them-

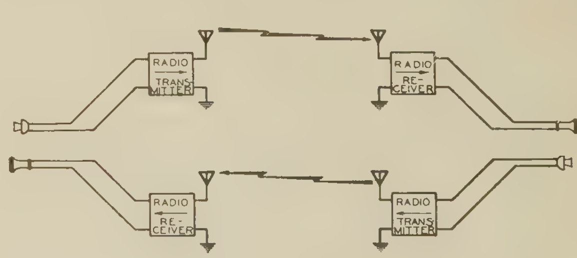


Fig. 5

selves. The problem remains of making them serve as a link between the two-wire systems on the two sides of the Atlantic. If this were merely one of transmission from one particular subscriber's set to another, the very simple arrangement shown in Fig. 5 would be feasible. In this, it may be noted that the eastbound and westbound transmission, each starting with a telephone transmitter at one end and extending

to a telephone receiver at the other, are kept entirely separate. Evidently, two people could carry on a converservation over this circuit without further complications; in fact, this was the manner in which the first two-way tests were carried out.

Since eastbound and westbound short-wave channels are at entirely different frequencies, there would be no interaction between the east- and west-going circuits when used in this way. For the long waves, however, since the east- and westbound circuits are at the same frequencies, each transmitting station would send considerable energy into the receiving station on the same side of the ocean, thus giving to each subscriber a

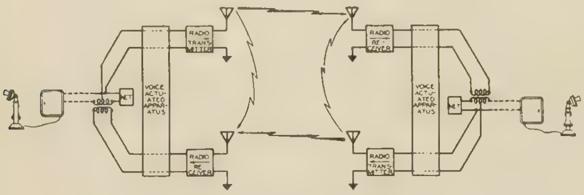


Fig. 6

heavy side tone of his own speech. This effect, however, could be reduced considerably by separating the transmitting and receiving stations and arranging the directive antennas of each receiving station so it would receive as little as possible of the corresponding transmitting station. Even with the long waves, a conversation could be held in this simple way.

When the east- and westbound radio circuits are brought together for a connection to a wire circuit at each end, as shown in Fig. 6, some very serious difficulties are introduced. Consider, first, the simpler case of the short waves where the eastbound and westbound transmission are at different frequencies.

The voice waves reaching London from an American talker will be reflected in part either at the London office where the east- and westbound channels are brought together or at some point before reaching the European subscriber. Unless means are taken to prevent it, this reflected energy can pass to the English transmitting station and be transmitted back to America. At the American end, a similar partial reflection can take place throwing part of the energy back again to England. In this way, according to circuit conditions, it is possible for the whole circuit either to build up and act as a widely flung oscillator, or, if the damping at the moment makes this impossible, electrical echoes and distortion can greatly interfere with the speaker or the listener.

In the case of long waves, as already noted there is the added difficulty that each transmitting station can throw a good deal of power into the receiving station on its own side of the ocean, thus bringing in the possibility of local oscillations and distortions.

For either the long or short waves, therefore, it is very advantageous,—in fact practically necessary,—to employ switching devices actuated by the voice waves themselves to prevent the effects just stated. In this diagram, there is drawn so as to involve the wire connections both to the transmitting and the receiving station at each end, a rectangle, labeled "Voice Actuated Apparatus." This is so arranged that when there is no transmission on the circuit, the wires connecting each transmitting station are short-circuited, making both transmitting stations inactive. Speech coming in, then, at one of the ends from a telephone subscriber operates a relay which opens the wire circuit to the transmiting station at his end, and at the same time, short-circuits the receiving path at the same end.

One interesting phase of this voice-operated switching mechanism is the employing of a delay circuit. At the New York terminal of the circuit, when the voice currents reach it from some distant subscriber, and after these voice currents have actuated the switching mechanism noted above, they pass into an artificial line, down which they travel, are reflected, and travel back to the sending end of the artificial line. In this way, the voice waves are allowed to idle away two one-hundredths of a second during which time the switching

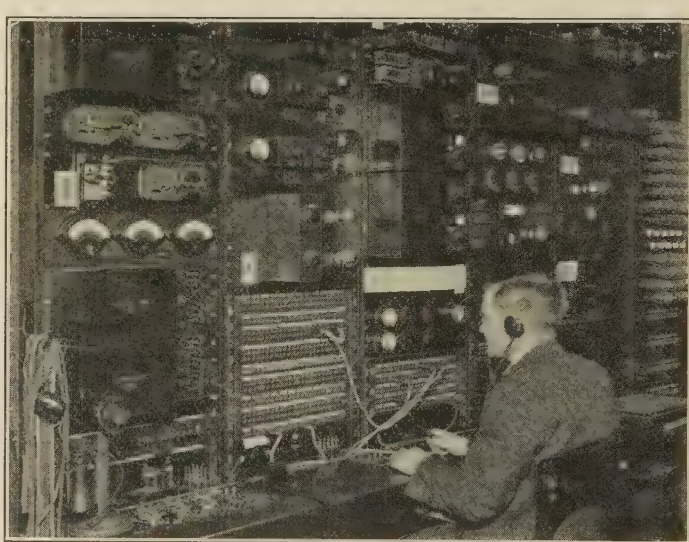


Fig. 7

mechanisms have performed the operations just noted and have thus put the circuit into shape for the voice waves to go forward.

In view of the character of radio and its variable nature in particular, during operation the circuit is under the constant supervision of two technical operators, one located in New York and one in London. Fig. 7 shows the special terminal equipment, meters, etc., and the technical operator at the New York end.

It is evidently desirable that the transmitting station shall always put out maximum power, whether the speaker has a loud voice or a weak vo ce or is near or distant from the transmitting station. One of the duties of the technical operator is to bring this about.

By proper indicating meters, he knows the power level of the speech going to his transmitting station, and he keeps this at the point where it will just completely load the transmitting station.

With this brief discussion, then, let it be assumed that conditions have progressed to the point where the two great telephone systems are joined together by the radio links.

To complete the story, the author wishes to say a few words more as to the changes and improvements which development work now under way is expected to give.

As the system stands today, it does not offer the same privacy as ordinary wire connections. While ordinary broadcasting sets are not of the proper type to receive messages from this system, with sets designed for the purpose it is comparatively easy to pick up one side of the conversation over the system by listening to the transmitting station in the same country as the listener. Because of the voice-actuated devices, the other side of the conversation has to be picked up directly from the distant country, which is a much more difficult thing to do.

Fig. 8

To give this system a high degree of privacy is difficult; particularly with the long waves. As already stated, the frequency range in which the long waves are situated is narrow and well-filled, so that any proposition that widens the required frequency range,—such, for example, as shifting the carrier frequency rapidly—cannot be employed. However, methods have been developed and equipment is now far advanced on a system that is expected to give conversations over this radio channel a sufficient degree of privacy. Certain features of this new privacy method will be probably in experimental use within a few months. But it will be at least six months, and possibly a year, before the complete privacy system is in full operation.

The feature of this whole transatlantic service which worries the engineer most, however, is the matter of reliability. After the engineer has done the best possible in transmitting and receiving stations, he is confronted by the fact that transmission through space and noise conditions varies so much that thousands of times as much transmitting power as would be sufficient under good conditions may under poor conditions be inadequate to get it through. His only defense is to use a considerable number of wavelengths which tend not to get into difficulties at the same times or under the same conditions.

Considering first the short waves, we find, as already noted, that there is sufficient difference between the transmission characteristics of different parts of the range from, say 10 meters to 30 meters, to improve the reliability considerably by designing the stations to use any one of three or more frequencies in this range.

We shall be very happy if, by such use of a number of short wavelengths and further improvements in technique, the reliability of short wave channels can be made such as to some day eliminate altogether the necessity of the long wave channel with its much more extensive plants. There are a number of projects going ahead in the world for the establishment of long distance transoceanic telephone circuits employing short waves alone. With a reasonable further development of the short wave art, undoubtedly such service will prove well worth giving.

Telephone service, however, is necessarily an exacting service, particularly since the subscribers participate directly in each connection. Moreover we are dealing here with the joining of North America and Europe, which, commercially and otherwise, is of such great importance that it justifies, perhaps, much more exacting technical requirements than any other transoceanic connection.

So far, data available regarding short waves do not suggest that they ever will give a reliability of service comparable to that for similar distances overland wire circuits. It is our present expectation, therefore, that the giving of suitable service between America and Europe will require the continuation of the long waves, even though such waves demand a much more extensive and complicated plant than do the short waves. In addition to the long waves, we shall also want the very best we can get from the short waves. By the combination of this one long and several short waves, we believe that ultimately the service, except for the three summer months of high static, will be but little interfered with by electrical weather, and that even for these months the service will be operative for better than 90 per cent of the time.

It will be understood, of course, that the connection today from London will be entirely by long waves, the short waves not being ready for commercial operation. The connection from America to England will be also in all probability by long waves, although the short waves are being held in readiness as an emergency routing.

The second list of projects, under the public buildings program, was recently sent to the House by the President. These projects provide for purchase of sites and construction in 93 cities throughout the United States, exclusive of Washington. They involve an expenditure in excess of $68,000,000 and an immediate expenditure in excess of $15,000,000.

ILLUMINATION ITEMS

By Committee on Production and Application of Light

A NEW INCANDESCENT LAMP WITH A NEW SIZE BASE*

Until recently, the application of incandescent lamps to certain decorative and display uses has been hampered because lamps fitted with the standard Edison screw base were too bulky and lamps for use on regular lighting circuit voltages could not be made easily with the small candelabra screw base. One base was too large to permit the desired delicacy of design in equipment in which the lamps were to be used; the other was too small from a standpoint of lamp performance and manufacturing difficulty.

A Mazda lamp, shown full size in Fig. 1, has now been placed on the market and gives promise of extensive use in several new fields. The lamp is made in three voltages—110, 115, 120. It consumes 10 watts and is regularly supplied in the S-11 bulb in red, yellow, green, blue, and amber-orange coated colors, flame tint, white, and clear. The base used on this lamp is illustrated in Fig. 2 which is also full size. It has been designated as the Intermediate screw base, No. 01301. The essential dimensions are indicated on the figure.

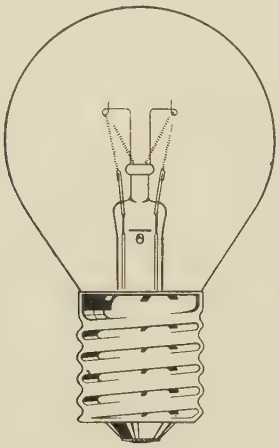


Fig. 1

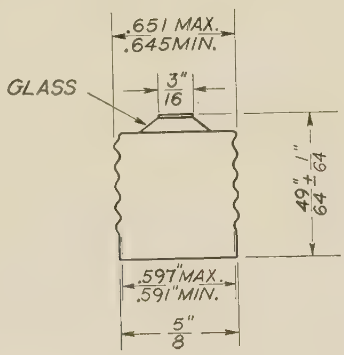


Fig. 2

This new lamp will find important use in sign and display work where its size will permit a narrow letter stroke and a presentation of detail in design beyond reach with the lamps fitted with the larger base. Also it will be used extensively in lighted ornaments where its size will permit pleasing and unusual effects to be obtained. Already these ornaments have become very popular abroad and will undoubtedly prove to be equally popular here.

A lamp of similar appearance with the same base has been made available for use on multiple-burning Christmas tree strings. The rapidly growing use of such strings in outdoor decorative lighting makes it particularly advantageous to use lamps in multiple rather than in series to facilitate replacement and to eliminate the extinction of several lamps through the failure of one.

*Submitted by Committee on Production and Application of Light.

CAN WE HAVE TOO MUCH LIGHT?

Although throughout the ages eyes have developed under thousands of foot-candles of daylight, we often encounter prejudice against comparatively feeble "high-intensity" artificial lighting on the ground of eye fatigue or actual damage to the eyes from supposedly excessive light. The idea that eye fatigue could result from working under intensities of illumination of the order of 50 to 100 foot-candles certainly did not emanate from scientific sources. Nor did this ungrounded contention arise from observation, for it has not been raised in connection with daylight, which, at the low value of 500 foot-candles, is generally considered "gloomy." On the contrary, there is evidence in every-day work indicating that an abundance of light makes work easier and hence less tiresome.

In order to study this, we devised a method to detect small changes in the balance of the eye muscles. This was applied to measure the effect of 30-min. periods of exacting visual work done under two intensities of illumination. One intensity of illumination was 5 foot-candles and was sufficient for the accomplishment of the visual work. The other was 100 foot-candles. Measurements were made upon the eye-muscles before and after each 30-min. work period.

Although the exhausting task was purposely chosen so that it could be performed under the lower intensity, the tests indicated that under twenty times this intensity of illumination, there was no greater eye-fatigue than under the lower intensity. In fact, the results showed slightly less eye fatigue in the case of the higher intensity of illumination.

Certainly, from the viewpoint of eye fatigue, we can safely recommend intensities of illumination at least as high as 100 foot-candles; and we see no reason why 1000 foot-candles should be fatiguing if other important factors of lighting and vision are properly handled.

Reference: "Eye Fatigue and Its Relation to Light and Work," by Dr. P. W. Cobb and Mr. F. K. Moss, *Journal of the Franklin Institute*, Vol. 200, 1925, p. 239.

INSTITUTE AND RELATED ACTIVITIES

The Summer Convention at Denver

Offers Good Papers and Delightful Trips and Entertainment

A program of excellent technical papers and most enjoyable recreational features has been scheduled for the 1928 Summer Convention which will be held in Denver, June 25-29, with headquarters at the Cosmopolitan Hotel.

Technical Session

Subjects alive in the minds of engineers will be treated in the technical papers. They will include such topics as surge-voltage investigations on transmission lines, control and protection of feeders for electrified railways, operation of electrical machines at high altitudes, a-c. elevator motors, electric welding of pipe lines, telephony, transmission experiences, extinction of a-c. arcs, high-frequency supervisory control and geophysical prospecting.

The year's advances in all lines of electrical engineering will be described in the annual reports of the Institute's Technical Committees.

Section and Branch Conferences

The annual conference of delegates from Sections will be held on the first day of the meeting, and there will also be a conference of Branch Counselors and Delegates.

Trips and Entertainment

Chief among the entertainment features will be an all-day trip through Denver's Mountain Parks. Private cars will take members through the pioneer town of Golden at the foot of Lookout Mountain. The climb up the mountain will be over the famous "Engineers Lariat Trail," to an elevation of 7600 feet. At the top a stop will be made to visit the grave of Buffalo Bill and Pahaska Tepee and to view the broad panorama of mountains and plains. The route will then lead over Genessee Mountain to Bergen Park and down the beautiful Bear Creek canyon on the return to Denver.

Trips may be made to the Valmont Steam Plant of the Colorado Public Service Company, Broadcasting Station KOA, stockyards and packing plants and other interesting points.

Golf and tennis tournaments will be played and a reception and a banquet are other features.

The ladies attending will of course enjoy the events already mentioned and in addition special plans have been laid for their entertainment, including teas, card parties, sightseeing and shopping tours.

In connection with the convention a most interesting tour of Yellowstone Park and other places has been arranged to start immediately after the convention closes, June 29. Details of this trip are published elsewhere in this Journal.

Railroad Rates

Regular Summer excursion rates will be available for members taking the trip to Denver who do not participate in the Yellowstone tour.

Committees

The General Convention Committee for the meeting is being directed by H. S. Sands, chairman; W. H. Edmunds, vice-chairman and R. B. Bonney, secretary. The officers of the various subcommittees are as follows: *Entertainment*—B. Shubart, chairman; H. B. Dwight, vice-chairman; *Finance*—W. C. Sterne, chairman; G. E. McCarn, vice-chairman; *Meetings and Papers*—H. P. Charlesworth, chairman; L. N. McClellan, vice-chairman; *Registration*—A. L. Jones, chairman; W. C. DuVall, vice-chairman; *Sections*—W. B. Kouwenhoven, chairman; V. L. Board, vice-chairman; *Ladies Entertainment*—Mrs. A. L. Jones, chairman; Mrs. L. N. McClellan, vice-chairman; *Hotel*—H. B. Barnes, chairman; J. H. McCable, vice-chairman; *Publicity*—J. F. Greenawalt, chairman; H. H. Argabrite, vice-chairman; *Transportation*—W. H. Edmunds, chairman; G. M. Moore, vice-chairman; *Student Branches*—J. L. Beaver, chairman; H. S. Evans, vice-chairman.

Following are tentative programs of events, technical sessions and ladies entertainment.

TENTATIVE PROGRAM OF SUMMER CONVENTION DENVER, COLORADO, JUNE 25-29, 1928

Monday, June 25

9:00 a. m.	Registration
10:00 a. m.	Section Delegates' Meeting
12:30 p. m.	Section and Branch Delegates' Luncheon
2:00 p. m.	Section Delegates' Meeting (continued)
4:00 p. m.	Branch Delegates' Meeting

Tuesday, June 26

9:30 a. m.	Annual Business Meeting of the Institute President's Address Presentation of Prizes for Papers Technical Session on Surge-Voltage Investigations
2:00 p. m.	Golf and Tennis Tournaments
8:30 p. m.	Lecture. *Geophysical Methods of Prospecting*, Dr. C. A. Heiland, Colorado School of Mines
9:30 p. m.	Reception

Wednesday, June 27

9:30 a. m.	Technical Committee Reports, Sessions B and C
12:30 p. m.	Directors' Luncheon-Meeting
1:30 p. m.	Technical Session on Electrified Railways
6:30 p. m.	Convention Dinner

Thursday, June 28

9:00 a. m.	Mountain Trip, returning about 4.00 p. m.
8:00 p. m.	Theater Party

Friday, June 29

9:30 a. m.	Technical Sessions, E and F
1:30 p. m.	Golf and Tennis Finals
7:20 p. m.	Start of Tour to Yellowstone Park, etc.

TECHNICAL SESSIONS

Tuesday, June 25, 9:30 a. m.

Session A—Surge Voltage Investigations

Surge-Voltage Investigation on Transmission Lines, W. W. Lewis, General Electric Co.

Lightning Investigations on New England Power Company's System, E. W. Dillard, New England Power Co.

Surge-Voltage Investigation on 140-kv. System of Consumers Power Co., J. G. Hemstreet and J. R. Eaton, Consumers Power Co.

Surge-Voltage Investigation 132-kv. Transmission Lines of American Gas and Electric Co., Philip Sporn, American Gas & Electric Co.

Surge-Voltage Investigation on 220-kv. System of Pennsylvania Power & Light Co., N. N. Smeloff, Pennsylvania Power & Light Co.

Wednesday, June 26, 9:30 a. m.

Sessions B and C—Technical Committee Reports, Two Simultaneous Sessions

WEDNESDAY, JUNE 26, 1:30 p. m.

SESSION D—ELECTRIFIED RAILWAYS—FEEDER CONTROL

High-Speed Circuit Breakers, J. W. McNairy and R. M. Spurck, General Electric Co.

High-Speed Circuit Breakers for Railway Electrification, H. M. Wilcox, Westinghouse Electric & Mfg. Co.

Operating Experience with High-Speed Circuit Breakers, B. F. Bardo, New York, New Haven & Hartford Railroad

Arrangement of Feeders and Equipment for Electrified Railways, R. B. Morton, of Gibbs and Hill

Protection of Electric Locomotives and Cars to Operate with High-Speed Circuit Breakers, J. V. Duer, Pennsylvania Railroad.

The High-Speed Circuit Breaker in Railway Service, W. P. Monroe and R. M. Allen, Illinois Central Railroad.

FRIDAY, JUNE 29, 9:30 a. m.

SESSIONS E AND F—TWO SIMULTANEOUS SESSIONS AS SHOWN BELOW

SESSION E

Operation of Electrical Machines at High Altitudes, H. S. Evans, University of Colorado

Transmission Experiences of the Public Service Co. of Colorado, M. S. Coover, University of Colorado, and W. D. Hardaway, Public Service Co. of Colorado

A-C. Elevator Motors of the Squirrel-Cage Type, E. E. Dresse, Lincoln Electric Co.

Electric Welding of Pipe Lines, J. D. Wright, General Electric Co.

SESSION F

Utilization of Lodgepole Pine as Pole Timber, R. W. Lindsay, Mountain States Telephone & Telegraph Co.

Carrier Systems on Long-Distance Telephone Lines, H. A. Affel and C. S. Demarest, American Telephone & Telegraph Co. and C. W. Green, Bell Telephone Laboratories, Inc.

Efficiency of Antenna Coupling to Power Lines, C. A. Boddie, Westinghouse Electric & Mfg. Co.

Superimposed High-Frequency Currents for Circuit-Breaker Control, L. R. Ludwig, Westinghouse Electric & Mfg. Co.

Extinction of an Alternating-Current Arc, Joseph Slepian, Westinghouse Electric & Mfg. Co.

LADIES PROGRAM

(The ladies are invited to all events of the convention. The following features are listed as being of special interest).

TUESDAY, JUNE 26

2:00 p. m.	Tea at Cherry Hills Country Club
8:30 p. m.	Lecture on "Geophysics" by Dr. C. A. Heiland, Colorado School of Mines
9:30 p. m.	Reception

WEDNESDAY, JUNE 27

11:30 a. m.	Bridge and Luncheon
6:30 p. m.	Convention Dinner

THURSDAY, JUNE 28

9:00 a. m.	Mountain Trip returning about 4.00 p. m.
8:00 p. m.	Theater Party

FRIDAY, JUNE 29

Morning	Automobile trip through city and shopping districts
7:20 p. m.	Start of tour to Yellowstone Park, etc.

Institute Tour to Yellowstone Park

Widespread interest is being shown in the Institute tour which will follow the Summer Convention in Denver. This tour as already announced in the JOURNAL will have as its main objective Yellowstone National Park and the route will pass through Colorado Springs and Salt Lake City.

With New York City as a starting point, the entire trip will be made in about eighteen days, including, the time spent in Denver at the Convention. The time required from other points will depend, of course, upon their location. The start will be made from New York on the afternoon of June 22 and the return to New York will be on July 10.

Members from other sections of the country may meet the party at any point along the route including Denver.

The party will arrive at Denver on Sunday evening, June 24, and after the Convention is over, will leave Friday evening, June 29, for Colorado Springs, where they will stay at the Broadmoor Hotel.

At Colorado Springs June 30, Pike's Peak, the Garden of the Gods, South Cheyenne Canyon, and Seven Falls will be visited. Enroute from Colorado Springs on July 1 will be seen the famous Royal Gorge.

Arriving in Salt Lake City on the morning of July 2, trips will be made morning and afternoon, and at noon the organ recital in the Mormon Temple will be heard. Among the trips which can be taken are those to Saltair Beach, the Bingham Copper Mines, and the canyons near the city.

Leaving Salt Lake City on the evening of July 2, the party will arrive at the West Yellowstone entrance on the next morning.

In Yellowstone National Park, four and one-half days will be spent enjoying the many wonders of nature which are there. Old Faithful and many other geysers, Yellowstone Lake, the Grand Canyon and Great Falls of the Yellowstone, Mammoth Hot Springs, Shoshone Lake and Dam are the prominent points that will be visited.

Leaving the park by way of the Cody road the party will take the train at Cody on the evening of July 7 and will arrive in Chicago July 9 and in New York, July 10.

A most enjoyable feature of this trip will be that all arrangements for railroad and pullman tickets, hotels, automobile tours, baggage transfer, etc., will be made by the travel bureau which has been authorized for the trip.

The cost of the tour, depending on pullman accommodations desired, will be as follows, with New York as the starting point. Rates from other points will differ according to the location.

COST OF TOUR STARTING AT NEW YORK

One in upper berth	One in lower berth	Two in compartment (each person)	Two in drawing room (each person)	Three in drawing room (each person)
\$350	\$375	\$398	\$439	\$393

The tour is arranged on the all-expense plan and the cost includes round-trip railroad and pullman transportation, side trips, accommodations at first class hotels (rooms with bath, twin beds) including the Cosmopolitan Hotel, the headquarters of the meeting, all meals (except at Denver), transfer of passengers and baggage, sight-seeing and touring cars, in fact all necessary expenses except meals at Denver, trips in Salt Lake City and tips.

The cost does not include private baths at Yellowstone Park. Such accommodations are limited, but private bath accommodations will be secured for members of the party who desire them there, at slight additional cost.

All who are interested in this tour are requested to communicate with the travel bureau, The Henry Tours, Inc., 565 Fifth Avenue, New York, N. Y., which will make arrangements. The bureau will give information on all matters.

New Haven Regional Meeting May 9-12

The Northeastern District will hold its fifth Regional Meeting as already announced in the JOURNAL at New Haven on May 9-12, with headquarters at the Hotel Taft.

With exception of one change the program will be as announced in the April JOURNAL, page 296. The change referred to is in connection with the trip to Hartford where inspection will be made of the mercury boiler and turbine installation of the

Hartford Electric Light Company and the Hartford Yard of the New Haven Railroad.

This Hartford trip will be made at 8:30 a. m., Friday, May 11, simultaneously with the trip to the Rocky River Hydroelectric Development.

Atlanta Regional Meeting October 29-31

A three-day regional meeting will be held under the direction of the Southern District of the Institute in Atlanta, Ga., October 29-31, with headquarters at the Hotel Biltmore.

Tentative plans for a program have already been formed by the District committee and further announcements will be made in future issues of the JOURNAL.

Pacific Coast Convention in Spokane August 28-31

The program is being completed for the 1928 Pacific Coast Convention which will be held in Spokane, Wash., August 28-31.

Among the subjects for the proposed technical papers will be transmission studies, including lightning phenomena, corona, and swinging of conductors; carrier-current relaying and communication; automatic stations; vacuum-tube applications; telephony, railway electrification, automatic train control, electrometallurgy of zinc, etc.

Details will be published in later issues of the JOURNAL.

Illuminating Engineers and New York Section to Hold Joint Session

On the evening of Friday, May 18th at 8.15 p. m. the New York Section of the A. I. E. E. and the Illuminating Engineering Society will hold a joint meeting in the Engineering Auditorium, 33 West 39th St., New York, N. Y. Two papers will be presented, as follows: "Gas-Filled Thermionic Tubes," by Dr. Albert W. Hull, of the General Electric Company and "Hot Cathode Neon Arcs" by Clifton G. Found, General Electric Company and J. D. Forney of the Cooper Hewitt Electric Company. Dr. Hull's paper will deal with cathode disintegration voltage, rectifiers, hot cathode lamps and thyrathrons. In their discussion of the neon discharge tube, Messrs. Found and Forney will describe its construction, electrical characteristics, luminous characteristics, design for a-c. and d-c. operation and its uses. It is expected that the talks will be accompanied by interesting exhibits and demonstrations.

World Engineering Congress, Tokio, 1929

Dr. Elmer A. Sperry, chairman of the American Committee of the World Engineering Congress to be held in Tokio, has announced the names of members of the various committees charged with carrying out plans for the undertaking. The Congress, which will be attended by engineers and scientists from all parts of the world, will convene in October of next year and the committees appointed will arrange for attendance and participation of American engineers at the Congress, which will be the first ever held.

The Committees follow:

Executive Committee: John W. Lieb, Chairman; Gano Dunn, George W. Fuller, Maurice Holland, Dugald C. Jackson, Frank B. Jewett, J. H. McGraw, O. C. Merrill, Charles F. Scott, Elmer A. Sperry, W. E. Wickenden and Calvin W. Rice.

Finance Committee: John W. Lieb, Chairman; Edward Dean Adams, W. W. Atterbury, W. L. Batt, Howard Coffin, E. M. Herr, Charles H. Herty, John Hays Hammond, William C. Potter, Charles M. Schwab, Alfred P. Sloan, Gerard Swope and Samuel M. Vauclain.

Technical Program Committee: Dugald C. Jackson, Chairman; H. Foster Bain, W. F. Durand, J. R. Freeman, Bancroft Gherardi, Allen Hazen, George W. Fuller, F. L. Hutchinson, Edgar Jadwin, A. E. Kennelly, Dexter S. Kimball, Arthur D. Little, Calvin W. Rice, F. R. Low, Michael I. Pupin, George T. Seabury, George Otis Smith, W. E. Wickenden and O. C. Merrill.

Transportation Committee: Frank B. Jewett, Chairman; C. O. Chesney, J. V. Davies, Howard Elliott, Maurice Holland, C. A. McAllister and H. H. Westinghouse.

Entertainment Committee: O. C. Merrill, Chairman; F. L. Hutchinson, Vice Chairman; Bancroft Gherardi, F. R. Low, J. V. W. Reynders, C. O. Mailloux and A. W. Berresford, of New York; Edgar Jadwin, John Halligan and John Hays Hammond of Washington; S. W. Stratton, Dugald C. Jackson, Arthur D. Little and A. E. Kennelly of Boston; C. F. Kettering of Detroit; E. M. Herr and L. A. Osborne of Pittsburgh; E. W. Rice, Jr., of Schenectady; Ambrose Swasey of Cleveland; Samuel M. Vauclain of Philadelphia; Charles A. Pratt of Chicago; W. F. Durand, C. E. Grunsky and Charles D. Marx of the Pacific Coast.

Publicity Committee: J. H. McGraw, Chairman, Charles H. Herty, Raymond C. Mayer, Calvin W. Rice, E. T. Mehren and Edward A. Simmons.

Promotion and Attendance Committee: George W. Fuller, Chairman; Edward Dean Adams, W. W. Atterbury, J. J. Carty, C. C. Chesney, Howard E. Coffin, Gano Dunn, John R. Freeman, George W. Fuller, Bancroft Gherardi, John Hays Hammond, Charles H. Herty, Samuel Insull, Arthur D. Little, William B. Mayo, Charles D. Marx, William Barclay Parsons, William C. Potter, E. Wilbur Rice, Jr., Charles M. Schwab, George Otis Smith, John F. Stevens, S. W. Stratton, Ambrose Swasey, Gerard Swope, Samuel M. Vauclain, H. H. Westinghouse and William E. Wickenden.

Radio Engineers Extend Invitation

At the June 6th meeting of the Institute of Radio Engineers to be held in the auditorium of the Engineering Societies Building, 33 West 39th Street, New York, two papers dealing with aircraft radio are to be presented. The first, by Dr. J. H. Dellinger and Mr. Haraden Pratt of the Bureau of Standards is entitled, "Development of Radio Aids to Air Navigation." The second paper will be presented by Mr. M. P. Hanson of the U. S. Naval Research Laboratory. It will be entitled, "Aircraft Radio Installations" and will be a description of various past and existing types of naval radio aircraft equipment.

Members of the American Institute of Electrical Engineers are especially invited to attend this meeting.

International Illumination Congress

Reports are being prepared for presentation at the International Illumination Congress, to be held in September at Saranac Inn., N. Y., when a new realization of the importance of proper illumination in all its aspects will be given to the people of the United States by the foremost lighting engineers of the world. On all the important branches of lighting, investigation is going forward, and among the subjects to be discussed are: Lighting for aviation, street and highway lighting, store and window lighting as an aid to retail selling, factory, library, hospital and public building illumination and floodlighting.

Not only will the laboratory and commercial practise in these subjects be reviewed and plans made for further work, but the foreign delegation will see much of American illumination practise. A tour which is being planned to take in a number of American cities in the eastern half of the United States will provide for inspection of important installations of all kinds.

Canada also is planning to welcome the delegation, with Niagara Falls and Toronto in its itinerary. Professor G. R.

Anderson of the University of Toronto, is preparing for the reception in his country.

Preparations are under the auspices of the Illuminating Engineering Society, of which Norman Macbeth, of New York, is President, and the U. S. National Committee of the International Commission on Illumination, headed by Dr. Clayton H. Sharp, of New York. The Executive Committee in charge of arrangements is proceeding under the direction of Julius Daniels of the Edison Electric Illuminating Company of Boston.

400 Attend Baltimore Regional Meeting

The Regional Meeting held in Baltimore, April 17-20, with headquarters at the Hotel Belvedere was marked by an attendance of four hundred, excellent discussion of the technical papers and splendid social and inspection features.

A digest of the discussion at the technical sessions will be published in the June issue of the Journal.

A feature of interest was the lecture on the evening of April 17 by Dr. R. W. Wood of Johns Hopkins University, entitled "Sounds That Burn."

Following the lecture two District Prizes for papers were presented by J. L. Beaver, vice-president in the Middle Eastern District. The prizes were for the best paper and for the best initial paper, and both were presented to Sigmund K. Waldorf for his paper, *An Amplifier to Adapt the Oscillograph to Low-Current Investigations.*

Two interesting inspection trips were held, one to the Gould Street Generating Station of the Consolidated Gas, Electric Light & Power Company, and the other to the Conowingo Hydroelectric Development of the Philadelphia Electric Company. The latter was an all-day trip on April 20 and was taken by about 150 members and guests.

A dinner-dance was held on the evening of April 18. During the dinner, President Bancroft Gherardi gave a short talk and an address was made by H. A. Wagner, president of the Consolidated Gas, Electric Light & Power Company.

A meeting of Counselors and Chairmen of the Branches in the District was held on the evening of April 19.

Two New Standards Available

AUTOMATIC STATIONS AND MATHEMATICAL SYMBOLS

Standards for Automatic Stations, No. 26 in the series of Institute Standards is now available in pamphlet form. This Standard was developed by the Technical Committee on Automatic Stations under the chairmanship of Chester Lichtenberg. It was approved as an A. I. E. E. Standard by the Board of Directors at their meeting of April 6, 1928. The standards apply to the following types of automatic power switching equipment: automatic machine equipment, automatic transformer equipment, automatic feeder equipment, automatic throw-over equipment, remote control equipment, supervisory equipment, remote metering equipment, load limiting and load indicating resistors. Cost of the pamphlet is 30 cents with 50 per cent discount to members.

Standards for Mathematical Symbols, No. 17f, was developed by the Sectional Committee procedure of the American Engineering Standards Committee and under the joint sponsorship of the American Association for the Advancement of Science, the American Society of Civil Engineers, the American Society of Mechanical Engineers, the Society for the Promotion of Engineering Education and the A. I. E. E. It represents the results of the work of one of the subcommittees of the Sectional Committee on Scientific and Engineering Symbols and Abbreviations, which is under the chairmanship of Dr. J. Franklin Meyer of the Bureau of Standards. It was approved by the Board of Directors of the Institute on June 23, 1927 and became an American Standard in January 1928. The other divisions of the Sectional Committee work will, it is hoped, shortly also become available. Mathematical symbols cover the following subjects; arithmetic and algebra, elementary geometry, analytic geometry, triogonometric and hyperbolic functions, calculus, special functions, vector analysis, etc. The pamphlet cost is 30 cents with 50 per cent discount to members. Address A. I. E. E. Headquarters, 33 West 39th Street, New York, N. Y.

A. I. E. E. Directors' Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Friday, April 6, 1928.

There were present: President Bancroft Gherardi, New York, N. Y. Vice-Presidents H. M. Hobart, Schenectady, N. Y., G. L. Knight, Brooklyn, N. Y., J. L. Beaver, Bethlehem, Pa., A. B. Cooper, Toronto, Ont.; Managers J. B. Whitehead, Baltimore, Md., E. B. Merriam, Schenectady, N. Y., M. M. Fowler, Chicago, Ill., F. C. Hanker, East Pittsburgh Pa., E. B. Meyer, Newark N. J.; National Secretary F. L. Hutchinson, New York, N. Y.

The minutes of the Directors' meeting of February 16, 1928, were approved.

Reports were presented of meetings of the Board of Examiners held March 21 and April 4. Upon the recommendation of the Board of Examiners, the following actions were taken: 54 Students were enrolled; 179 applicants were elected to the grade of Associate, 1 applicant was elected to the grade of Member; 25 applicants were transferred to the grade of Member; 1 applicant was transferred to the grade of Fellow

Approval by the Finance Committee for payment, of monthly bills amounting to $38,316.77, was ratified.

Voted to join with other American national engineering societies in contributing the sum of $100 each to the Association of American Engineers in France, to assist the Association in becoming established.

Upon the recommendation of the Publication Committee, the following amended by-law (Sec. 96) was adopted:

"Section 96. The National Secretary is authorized to receive from non-members annual subscriptions to the quarterly Transactions, in pamphlet binding, at ten dollars ($10.00) per year, a discount of 50% to be allowed to college and public reference libraries and 20% to publishers and subscription agents. Members of the Institute may subscribe to the quarterly Transactions, in pamphlet binding, at five dollars ($5.00) per year, of which three dollars ($3.00) shall be deducted from the subscriber's annual dues and two dollars ($2.00) paid directly by the member. The price of single copies shall be two dollars and fifty cents ($2.50) to non-members, with the usual discounts, and one dollar and twenty-five cents ($1.25) to members.

"Orders for the quarterly Transactions, in cloth binding, may be accepted from non-members at a price of twelve dollars ($12.00) per year with a discount of 50% to college and public reference libraries and 20% to publishers and subscription agents. Orders may be accepted from members at seven dollars ($7.00) per year, of which four dollars ($4.00) shall be paid directly by the subscriber and the balance of three dollars ($3.00) deducted from his annual membership dues. Single copies shall be sold to non-members at three dollars ($3.00) per copy, and to members at two dollars ($2.00) per copy.

"Back volumes of the quarterly Transactions may be sold to members and non-members at the subscription prices previously quoted for the current edition. Back volumes of the Transactions published in annual form prior to 1928 may be obtained by non-members at ten dollars ($10.00) per year or at such lower prices as may be authorized by the Board of Directors, with the usual discounts. Members of the Institute may obtain copies of the back volumes issued in annual form at the members' subscription price, or at a discount of 50% from the non-member price for volumes published prior to 1921."

Authorization was given for the establishment of Student Branches of the Institute at the University of Louisville and the University of Vermont.

Ratified the appointment by the President of the following Committee of Tellers to canvass and report upon the votes cast for the election of officers and constitutional amendments:

Messrs. R. R. Kime, Chairman, W. E. Coover, E. E. Dorting, W. S. Hill, D. B. Perry, H. O. Siegmund, and John T. Wells.

Professor Charles F. Scott was reappointed as an Institute representative upon the Commission of Washington Award, for the two-year term commencing June 1, 1928.

Upon the recommendation of the Standards Committee, Standards for Automatic Stations (No. 26) were approved as A. I. E. E. Standard.

The official invitation to this Institute, from The Kogakkai, of Japan, transmitted through the Department of State, to participate in the World Engineering Congress, Tokio, Japan, October 1929, was presented, and the following resolution was adopted:

WHEREAS, the American Institute of Electrical Engineers has received from the Department of State of the United States of America, an invitation to participate in a World Engineering Congress to be held in Tokio, Japan, in October 1929.

RESOLVED: That this organization is pleased that a World Engineering Congress is to be held in 1929 and considers it most appropriate and satisfactory that the Congress is to be held in Tokio, Japan, under the auspices of The Kogakkai; and

RESOLVED FURTHER: That the American Institute of Electrical Engineers accepts with pleasure the invitation to take part in this Congress and will heartily cooperate through the American Committee toward making the Congress a success.

Other matters of importance were discussed, reference to which may be found in this and future issues of the JOURNAL.

Engineers' Memorial at Louvain

Louvain's new library and the memorial carillon and clock in its tower are progressing satisfactorily. There is yet time, however, before dedication on the 4th of July for thousands more of American engineers to have shares in this tribute to those who gave their lives in the Great War. A larger number of participants is desired to make our memorial more fully an expression of goodwill to our friends in Europe from the whole membership of the engineering societies of the United States.

The Committee presents an accounting to show this need for action by a much greater proportion of the 75,000 or more engineers in our societies.

Contributors to the fund to 10th April		2659
Of the 75,000 eligibles, the contributors are only		3½%
Funds contributed to 10th April		$62,112.

Besides this sum, there have been gifts of materials and services. For the expenses for raising the fund, separate provision has been made.

Obligations total, approximately		$83,000
Contracts for clock and carillon, about	$71,200	
Perpetual maintenance fund	10,000	
Tablets, memorial volumes and other minor items, about	1,800	
Excess of obligations over contributions to date		$21,000
Payments already made on obligations		$30,000

Other payments will be due soon and the final payments in August.

Contributions should be sent to United Engineering Society, 29 West 39th Street, New York, at your early convenience.

EDWARD DEAN ADAMS, Chairman

New York Electrical Society to Visit East River Generating Station

At 12-30 p. m. on Saturday, May 12, the New York Electrical Society will be the guests of the New York Edison Company in an inspection of their new East River Generating Station. A buffet lunch will be served to the members and their friends attending. Participation in this trip will be by ticket only. For further details communicate with H. E. Farrer, Secretary New York Electrical Society, 29 West 39th Street, New York, N. Y.

E. J. Prindle Addresses Law Association

At the Waldorf-Astoria Hotel, February 9, 1928 before 24 Federal judges and 600 patent lawyers and their guests, Mr. E. J. Prindle, President of the New York Patent Law Association, delivered an address on "The Marvelous Performance of the American Patent System," in which he briefs the many achievements of American inventions and work of the United States Patent Office, in view of which Mr. Prindle states that "the dreams which once seemed beyond belief pales in the light of actual accomplishment." Continuing, Mr. Prindle cited the fact that from 1880 to 1890 inventions of first importance produced by American inventors were too numerous to enumerate. Including the Westinghouse quick-acting air brake the Janney car coupler; the transparent photographic film—forerunner of motion pictures; the recording adding machine; the linotype and various other type-setting machines; the half-tone process; the Tesla split-phase induction motor; the incandescent lamp; the transformer; steam turbine; electric furnace; polyphase electric motor; the cash register; the trolley car; and electric welding. Two-thirds of all inventions of primary importance registered since the establishment of the Patent System have been of American production, and the American Patent System, Mr. Prindle believes, is the most marvelously effective economic instrument ever devised by man.

Because that instrumentality has produced such remarkable results, it should be guarded from any experiment with changes in principles and attempts to improve it should be confined to matters which make for simplification of procedure.

A New College of Engineering

Because of the demand for engineering education and the need of industries in southern California for centralized and adequately-equipped engineering laboratories the board of trustees of the University of Southern California has authorized the creation of a college of Engineering, of which Philip S. Biegler, professor of electrical engineering at the University for the past five years, has been appointed acting dean by President Rufus B. von KleinSmid.

The new college, which will open September 1928, will be made up of five major divisions with separate chairmen as follows: Chemical Engineering, Professor Wilfred W. Scott; Civil Engineering, Professor Robert M. Fox; Electrical Engineering, Professor Philip S. Biegler; Mechanical Engineering, Professor Thomas T. Eyre; Petroleum Engineering, Professor Allan E. Sedgwick.

In addition to the four-year courses leading to a B. S. degree in any of the divisions of engineering, and a Master's degree for graduate work, a degree of C. E. has been established for distinction in the practise of engineering.

Professor Biegler, came to Southern California five years ago after 13 years of teaching at the Universities of Iowa, Illinois, Purdue, and Washington State College, and a number of years with the Commonwealth Edison Company in Chicago and and the Washington Water Power Company of Spokane in an Engineering capacity. From 1918 to 1921 he was associate engineering editor of *Electrical World*. He has written extensively on educational problems and engineering subjects; is a Member of the Institute since 1913; past chairman of the Urbana Section; present chairman of the Committee on Student Activities of the Pacific District and a member of the Executive Committee of the Los Angeles Section. He is also a member of the Society for the Promotion of Engineering Education, the American Association of University Professors and the Engineers' Club of Los Angeles. He is a graduate of the University of Wisconsin with the degree of B. S. in E. E. (1905), and E. E. (1915), and M. S. in E. E. by the University of Illinois (1916.)

Engineers Public Works Bill Hearings Started

The Wyant Public Works Bill, H. R. 8127, is the subject of hearings started before the House Committee on Expenditures in the Executive Departments on April 4.

Congressman Wyant opened the hearing with a strong statement in behalf of the measure. He was followed by Judge Finney, Assistant Secretary of the Department of the Interior, and Dr. George Otis Smith, Director of the Geological Survey both of whom favor the reorganization plan proposed in the bill.

On the second day of the hearing, President Berresford, of American Engineering Council, gave a summary of the work that has been done in behalf of the measure, especially referring to the practically unanimous sentiment in favor of the bill, by organized engineers. He was followed by E. O. Griffenhagen, prominent organization expert, member of American Society of Mechanical Engineers, and member of American Engineering Council's Committee on Reorganization of the Executive Departments, who explained in some detail, the desirability and feasibility of coordinating the engineering functions of the Federal Government. General R. C. Marshall, Manager of the Associated General Contractors of America, followed with a statement that the contractural relations of the Federal Government would be greatly improved by the concentration of this work.

On the following day other prominent contractors such as, John W. Cowper of Buffalo, and Colonel D. H. Sawyer of Washington, testified in behalf of the measure. Dr. Elwood Mead, Director of Reclamation, and Farley Osgood followed, concluding the argument in behalf of the measure, making especially strong argument for it. Mr. Osgood referred especially to the analogous situation in industry where great industrial plants found it necessary to have a coordinated engineering division.

The opposition headed by the representatives of the Corps of Engineers, U. S. Army, will consume several days in presenting its testimony. This will be followed by rebuttal testimony from the engineers.

The Montefiore Prize

The Montefiore Electrotechnical Institute of Liége Belgium, is announcing the conditions of the George Montefiore Prize, which will be awarded in 1929.

The prize, which consists of the interest on 150,000 Belgian francs at three per cent, is given triennially in international competition for the best original work presented on scientific advancement and on progress in the technical applications of electricity in all fields. Only works presented during the three years preceding the award will be considered. They may be submitted in English, in printed or manuscript (typewritten) form. The Director of the Montefiore Electrotechnical Institute presides over the jury, which is composed of five Belgian and five foreign electrical engineers.

Report of Boulder Dam Bills

The Senate and House Committees have submitted reports on the Swing-Johnson Boulder Dam Bills.

The majority reports favoring the measure were submitted in the Senate by Senator Johnson of California and in the House, by Congressman Swing of California.

Three minority reports have so far been submitted. The first was by Congressman Douglas, an engineer from Arizona. His opposition is "based upon a matter of principle and upon the unsound economic nature of this measure."

Following this report, Congressman Leatherwood submitted a detailed report in which he states that it is "a scheme to secure construction by Federal Government of a power project under the guise of flood control and irrigation."

The minority report submitted by Senator Ashurst opposes the bill on the ground that it invades state rights in an unconstitutional manner, which he warns, will cause expensive and protracted litigation. Opposition to the Boulder Dam project is declared also by a special committee appointed by the American Engineering Council to examine the question from an engineering standpoint. The committee, of which Francis Lee Stuart of New York is chairman, says in its report:

"Your committee is unanimously agreed that the information set forth in the reports which have been submitted to us is not conclusive as to the engineering feasibility of the plan outlined in the Swing-Johnson bill and that before either the Government or private capital would be justified on engineering or economic grounds in committing themselves to the expenditure involved, the development of the river for the purpose in view should be further and most thoroughly investigated to determine how the results which it seeks to accomplish can be secured with a reasonable assurance of success."

Other members of the Council's committee are Allen Hazen, Clemens Herschel, J. Waldo Smith, and Lewis Buckley Stillwell.

Engineering Rise in Radio

The above is the title of a serial account of the rise and progress of radio from the engineering and invention points of view, which has been written by Donald McNicol, past-president of the Institute of Radio Engineers and Fellow of the Institute. The story begins in the June 1928 issue of the magazine *Radio Engineering*, and will be continued in the monthly issues throughout the year.

Fellowships and Scholarships in Electrical Engineering at North Carolina State College

The North Carolina State College of Agriculture and Engineering announces the following fellowships and scholarships:

One half-time teaching fellowship in electrical engineering paying $750 for a period of ten months, with the possibility of re-appointment for the second year, at the end of which time the requirements for the Master's degree should be completed.

Eight $450 fellowships and six $225 scholarships, of which probably not more than two will be in electrical engineering.

Further information may be secured from Professor C. W. Ricker, Department of Electrical Engineering, State College Station, Raleigh, N. C.

Chicago Office of Employment Service to Have New Quarters

The Chicago office of the Engineering Societies Employment Service, which is operated under the direction of the national societies of Civil, Mining, Mechanical, and Electrical Engineers, and the Western Society of Engineers, will be located in the new Engineering Building, 205 West Wacker Drive, after May 1, 1928.

Information concerning the three offices of the Service may be found under the heading "Engineering Societies Employment Service" in each issue of the JOURNAL.

PERSONAL MENTION

ALBERT J. PYLE, formerly of Wilmington, Del., is now associated with the Ford Instrument Co., Long Island City, N. Y., as technical writer.

E. A. BROFOS, European commercial manager of the International Standard Electric Corporation has been made vice-president of the Corporation with headquarters in London, England.

HENRY W. REDING has been appointed textile engineer of the Westinghouse Elec. & Mfg. Co., in charge of the company's

activities at East Pittsburgh and will be responsible for the application and success of the textile equipment of Westinghouse customers there.

J. P. Putnam, formerly employed as engineer in the Radio Dept. of the Martin Copeland Company, Providence, R. I., for radio research and development, is now employed as engineer of the National Company, Malden, Mass., doing similar work.

Robert J. Deneen and Frederic Attwood were elected vice-presidents of the Ohio Brass Company at a meeting of the Board of Directors held February 3, 1928. Mr. Deneen is in charge of the company's sales activities in the Chicago district, while Mr. Attwood is in New York in charge of the eas ern sales district.

George B. Tripp has joined the organization of Glidden, Morris and Company, Investment Bankers, New York City. For many years Mr. Tripp has been engaged in the executive management and operations of various public utility properties in this country, and was formerly vice-president of the United Gas & Electric Engineering Corporation, more recently he has been in charge of the operations of the Huntington Development and Gas Company, a subsidiary of the Columbia Gas and Electric Corporation, at Huntington, West Virginia.

Obituary

Harry G. Hopkins, of Norwood, Ohio, who joined the Institute May 1918, died March 27 1928. Mr. Hopkins was born at Brocton, New York, the 7th day of September 1884. He attended the local High School and then entered Syracuse University, graduating with the class of 1909. It was here he obtained his E. E. degree. During High School and College vacations he was obtaining practical knowledge by work with Portland Telephone Co., Brocton, N. Y., the Brocton Fire Alarm in design and construction work and the Crandall Panel Co. on shop and inspection work. He was also doing house and store wiring on his own responsibility. Immediately after finishing his college course, he apprenticed himself to the Westinghouse Electric & Mfg. Co., for five months doing shop work, spending three months in the Testing Department, 13 months in the Engineering Dept. and three months in the Detail and Supply Dept., where his work was the drawing up of switchboard specifications with detail relative thereto. In 1911 he was transferred to the Cincinnati Office on like work, but in 1914 he left the Westinghouse Company to identify himself with Albert Emanuel Co., of Dayton, Ohio, where his work was general engineering on electric railways and ice plants, investigating the reporting on public utilities properties as to the desirability of purchase, the appraisal of electric properties and assisting in obtaining securities. In April 1916, however, he returned to the Westinghouse Company, East Pittsburgh, as a specialist on lightning protection apparatus, miscellaneous fuses, switches, carbon and oil circuit breakers and their application. For the past several years, Mr. Hopkins has been electrical engineer at the Edgar Thompson Works of the Carnegie Steel Co., Swissvale, Pa. This was his connection at the time of his death.

James J. Wood, engineer and inventor, consulting engineer at the Ft. Wayne Works of the General Electric Company and Fellow of the Institute since 1918, died April 20, at Ashville, N. C. Mr. Wood was born at Kinsale, County Cork, Ireland, but came to the United States at an early age and attended the public schools at Branford, Conn. In 1878 he was graduated from the night school of the Brooklyn Polytechnic Institute and twelve years later had achieved the factory managership and position of chief engineer of the Fort Wayne Works of the General Electric Company. Mr. Wood had 240 patents to his credit for electrical and mechanical inventions including lighting systems, machines, lamps cutouts, switchboards, suspensions and hoods. It was he who engineered the first electric floodlighting of the Statue of Liberty, in 1885; from 1900 to 1918, he was occupied with the development of d-c. generators and motors, a-c. generators, transformers, meters, reactance regulators for series a-c. lamps, enclosed a-c. lamps, magnetite lamps, single-phase a-c. motors, circuit breakers and numerous small motor applications, such as vibrator, utility motors and series contactors. He was concerned in the manufacture of the Brayton oil engine installed in the first Holland submarine, built the first lamps for Sir Hiram Maxim and machines for constructing the main cables used on the original Brooklyn Bridge.

W. F. M. Goss, retired educator, past president of the American Society of Mechanical Engineers and an Associate of the Institute since 1908 died March 23, 1928. Doctor Goss was born at Barnstable, Mass., October 7, 1859. Upon the completion of a two years' course at Purdue, he was appointed instructor in practical mechanics and at once began the work of establishing shop laboratories. His first class was one of five students, but the work broadened rapidly, the equipment was increased, the students becoming so numerous that new laboratories must be built. In 1883 he became professor of practical mechanics, a title which he held for seven years. So successful was his work that the cities of Chicago, Toledo, Louisville and Indianapolis in turn sought the aid of the Purdue laboratories, (to which many a distinguished visitor came,) to help them establish their own manual training schools. Much of the equipment was made at the University of Purdue and supplied complete to these other school boards. In 1889 Dr. Goss obtained leave of absence and took up his residence in Boston. Some work was done by him at the Massachusetts Institute of Technology, but in 1890 he was appointed Professor of Experimental Engineering at Purdue. Having developed laboratories for elementary engineering training, it was now his work to build for more advanced engineering work. Plans for an extensive laboratory were developed and by the fall of 1891 a portion of the building was constructed. In 1899 he was granted a year's leave of absence which he spent in study and travel abroad. Upon his return he was appointed Dean of the School of Engineering, Purdue. After 28 years of faithful service he resigned his position at Purdue to take up what seemed to him a larger field as Dean of the College of Engineering of the University of Illinois. Dr. Goss retired from active business in 1925 and returned to Barnstable, the place of his birth. He held an M. A. from Wabash college; an honorary degree of Doctor of Engineering from University of Illinois; was a member of the American Society for Testing Materials, the Society for the Promotion of Engineering Education, the Executive Committee of the National Advisory Board, the Master Car Builders' Association, the Illinois Academy of Science and the Western Society of Engineers. He was a Fellow of the American Society of Advancement of Science, a member of the Railroad Club of New York, past-president of the Western Railway Club and was chairman of the Advisory Committee organized by the Pennsylvania Railway Company.

T. A. Wilkinson, Electrical Engineer, New England Public Service Co., Augusta, Me., died Monday, April 2, at the age of 53. Mr. Wilkinson was a Fellow in Electrical Engineering, School of Practical Science, Toronto University, and had done much in the practical engineering field as assistant electrical engineer of the Pittsburgh Reduction Co., assistant and then head of the statistical department Westinghouse Church Kerr & Co. General manager and electrical engineer of the Electro Tin Products, Ltd., engineer, railway department, the Hydro-Electric Power Commission of Ontario, assistant electrical engineer of the Public Utilities Commission, London, Ontario, Canada and special engineering work on transmission and distribution for the Westinghouse Electric & Mfg. Co. Mr. Wilkinson was a Canadian by birth. He became an Associate of the Institute in 1926.

Howard Ford Thurber, former president and chairman of the Board of Directors of the New York Telephone Company, died

at his home in this city April 22, 1928. Mr. Thurber was born in Brooklyn August 6, 1869, and was educated at the Brooklyn Polytechnic Institute. He obtained an M. E. degree from Cornell University in 1890 and that same year became assistant engineer of the Metropolitan Telephone & Telegraph Company, from which position he rapidly advanced to that of assistant chief engineer in 1893 and general superintendent the following year. In 1906 he was chosen general manager of the New York Telephone Company and here again he went ahead with rapid progress from vice-president to president and director. Mr. Thurber was active in many other companies' interests, as vice-president of the Eastern Group of Telephone Companies, president and director of the New York Telephone Realty Corporation and the Empire City Subway Company; director of the Bell Telephone Company of Pa. and associated companies; the Chesapeake Telephone Company and associated companies; the Mountain Home Telephone Company, the Holmes Electric Protective Co., and the Friendship Telephone Company. He was also a member of the Metropolitan Museum of Art, the Merchants Association of New York, the New York State Chamber of Commerce, the University Club, the St. Maurice Fish and Game Club and the Railroad Club of New York. Mr. Thurber joined the Institute in 1896.

A. L. Broomall, aged 44 years, manager of the Renewal Parts Engineering Department of the Westinghouse Electric & Manufacturing Company, died Tuesday morning, April 10, in his home, 814 Mifflin Avenue, Wilkinsburg, of pneumonia. Mr. Broomall was born June 27, 1884, in Lenni, Delaware County, Penn., and was educated at the Westchester State Normal School and Lehigh University, graduating from the latter institution in 1906 with the degree of Bachelor of Science in Electrical Engineering. Immediately thereafter he entered the graduate students' course of the Westinghouse Company, where he continued work until his death.

His advancement as an engineer was rapid. His first important work was on the installation of the first electric locomotives on the New York, New Haven and Hartford Railroad. From 1911 to 1915 he had charge of the design of electrical vehical motors; he was appointed section head of the d-c. motor section in 1915, and in 1922 he was transferred to the renewal parts engineering department as engineer-in-charge, later becoming manager of the department, which was the position he held at his death,

He was a member of Beta Lodge, F. and A. M., Wilkinsburg, and the American Electric Railway Association. Mr. Broomall joined the Institute in 1909 as an Associate but advanced to the full grade of Member in 1913.

A. I. E. E. Section Activities

Future Section Meetings

Cleveland

Annual Meeting. Speaker: Pres. Bancroft Gherardi, Vice-President and Chief Engr., American Tel. & Tel. Co. (National President, A. I. E. E.) May 24.

Columbus

Household Electrical Engineering, by G. W. Alder, Consulting Engineer, Good Housekeeping Institute. Annual Meeting. Election of officers. Ladies are invited to this meeting, which will be preceded by a dinner. May 25.

Erie

Modern Reproduction Of Sound, by L. T. Robinson, General Engineering Laboratory, General Electric Co. May 15.

New York

Illumination Session. May 18.

Niagara Frontier

Electrification of the Cement Industry, by J. A. Zook, Chief Engr., Great Lakes Portland Cement Co. of Buffalo. May 18.

Pittsburgh

Household Electrical Engineering, by G. W. Alder, Consulting Engr., Good Housekeeping Institute. Dinner Meeting, to which the ladies are invited. May 8.

St. Louis

Influence of Iron Saturation on the Operation Characteristics of Transformers, by H. Weicshel, Wagner Electric Corp. May 16.

Sharon

Banquet Meeting. "The Psychology of Laughter," by Charles Milton Newcomb. June 5.

Vancouver

Annual Meeting and Dinner. June 5.

RECENT DEVELOPMENTS IN THE DIAL SYSTEM OUTLINED TO NEW YORK SECTION

OFFICERS FOR 1928-29 ANNOUNCED

On Thursday, April 19th, the New York Section of the Institute held its third annual Student Convention and regular monthly Section meeting. The Student Convention is outlined in detail elsewhere in this issue. The Section meeting, held at 8:15 p. m. in the Engineering Auditorium was devoted to a talk on "Some Recent Developments in Dial Systems," by W. E. Farnham and H. M. Bascom of the A. T. & T. Co. Due to the sudden illness of Mr. Farnham, the talk was given by W. D. Sargent also of the A. T. & T. Mr. Sargent's talk was profusely illustrated by lantern slides and moving pictures. An introductory talk was given by K. W. Waterson, asst. vice-president of the A. T. & T. Co.

The announcement of the election of Section officers for 1928-1929 was made by Chairman L. W. W. Morrow, as follows: R. H. Tapscott, Chairman; H. S. Sheppard, Secretary-Treasurer; and for Executive Committee, J. T. Barron and T. F. Barton.

PAST SECTION MEETINGS

Atlanta

A Solution of Power Factor Correction, by B. T. McCormick, Wagner Electric Corp. Illustrated with slides. Joint meeting with Georgia School of Technology Branch. A dinnder preceded the meeting. March 30. Attendance 120.

Boston

Where Are We Going in the Electric Light and Power Industry? by W. S. Murray, Consulting Engineer. March 16. Attendance 350.

Heaviside and Steinmetz, Their Work and Personalities, by Dr. Ernst J. Berg, Union College. March 30. Attendance 150.

Cincinnati

Modern Developments in the Elevator Industry, by E. W. Yearsley, Otis Elevator Co. March 8. Attendance 56.

Cleveland

High-Speed Traction Motors, by N. W. Storer, Westinghouse Electric & Mfg. Co. March 8. Attendance 60.

Applications of Automatic Switching, by R. W. Osterholm, student; and

Problems in Converter Stations, by R. G. Hornberger, student. Illustrated with slides. Talks on activities of Student Branches were also given by Prof. J. L. Beaver, Vice-President, Middle Eastern District, and J. G. Currie, Chairman, Case School of Applied Science Branch. Joint meeting with Case School of Applied Science Branch. March 22. Attendance 140.

Connecticut

Research and Invention, by Thomas Spooner, Westinghouse Electric & Mfg. Co. Illustrated with slides. March 13. Attendance 70.

Denver

Financial Supervision of a Large Engineering and Manufacturing Organization, by C. H. Lang, General Electric Co. A dinner preceded the meeting. March 13. Attendance 50.

Detroit–Ann Arbor

Transatlantic Radio, by Dr. Austin Bailey, American Tel. & Tel. Co. Joint meeting with Institute of Radio Engineers. March 20. Attendance 240.

Erie

Tendencies in Modern Transportation, by N. W. Storer, Westinghouse Electric & Mfg. Co. March 20. Attendance 125.

Indianapolis–Lafayette

Protection of Transmission Lines and Apparatus against the Effects of Lightning, by K. B. McEachron, General Electric Co. March 6. Attendance 155.

The Televox, by R. J. Wensley, Westinghouse Electric & Mfg. Co. March 27. Attendance 350.

Louisville

Engineering and Engineering Education, by Dean A. A. Potter, Purdue University. Joint meeting with A. S. M. E. March 20. Attendance 62.

Radio Interference, by A. W. Lee, Louisville Gas and Electric Co. April 9.

Lynn

Motion pictures, entitled respectively, "Saving Coal at Home" and "Through Oil Lands of Europe and Africa," were shown. A film, showing the recent New England flood, was also shown. March 22. Attendance 170.

Heaviside and Steinmetz, Their Work and Personalities, by Dr. Ernst J. Berg, General Electric Co. Annual Dinner. March 31. Attendance 291.

Madison

Electric Utility Rates, by G. C. Neff, Vice-President, Wisconsin Power & Light Co. March 30. Attendance 25.

Mexico

Automatic Substations, by B. J. Skarbovick. Dinner meeting. March 6. Attendance 36.

Milwaukee

Atoms as Wonder Workers, by H. D. Hubbard, National Bureau of Standards. Joint meeting with Engineers' Society of Milwaukee. March 21. Attendance 450.

Nebraska

Manufacture of Porcelain Insulators, by C. A. Brunner, Locke Insulator Corp. Illustrated with motion pictures. A dinner preceded the meeting. February 7. Attendance 50.

The Street Railway Problem in Omaha, by J. N. Shanahan, President, Omaha and Council Bluffs Street Railway Co. March 20. Attendance 55.

Niagara Frontier

Automatic Control of Substations by Means of Supervisory Control and Other Methods, by R. J. Wensley, Westinghouse Electric & Mfg. Co. March 2. Attendance 170.

Oklahoma

New and Better Business, by S. A. Chase, Westinghouse Electric & Mfg. Co. March 13. Attendance 150.

Philadelphia

Research and Invention, by Thomas Spooner, Westinghouse Electric & Mfg. Co. Illustrated with slides. A dinner preceded the meeting. March 12. Attendance 105.

Pittsburgh

Vacuum-Tube Applications, by T. A. E. Belt, General Electric Co. March 13. Attendance 265.

Pittsfield

The Interconnection of Power Systems, by Philip Sporn, American Gas & Electric Co. Illustrated with slides. March 20. Attendance 135.

Electrical Accidents, by H. M. Jalonack, General Electric Co. Illustrated with slides and a motion picture entitled "Resuscitation." March 27. Attendance 100.

The Psychology of Laughter, by C. M. Newcomb. Annual Dinner. The Best Paper Prize of the Pittsfield Section for the Season 1926-1927 was awarded at this dinner to Mr. G. Camilli for his paper entitled "Reduction of Transformer Exciting Current to a Sine Wave Basis," presented in May 1927. April 3. Attendance 246.

Providence

Application of Electricity to Marine Service, by F. E. Smith, General Electric Co. February 7. Attendance 40.

Reminiscences of Heaviside and Steinmetz, by Dr. Ernst J. Berg, Union College. February 29. Attendance 50.

Rochester

Television, by H. M. Stroller, Bell Telephone Laboratories. Illustrated by slides and motion pictures. A dinner preceded the meeting. March 2. Attendance 578.

St. Louis

Artificial Light and Civilization, by Dr. M. Luckiesh, National Lamp Works of General Electric Co. Joint meeting with A. S. M. E. March 28. Attendance 150.

San Francisco

Mechanical Movements of Line Conductors under Short-Circuit Conditions, by W. S. Peterson, Los Angeles Bureau of Power and Light. Illustrated with slides. March 23. Attendance 52.

Schenectady

Size of the Universe, by Dr. I. Langmuir, General Electric Co. Illustrated with slides. March 16. Attendance 400.

Toronto

The Distribution of Power in the Rural Districts of Ontario, by R. E. Jones, Hydro-Electric Power Commission. February 9. Attendance 51.

Instruments Transformers, by A. M. Wiggins, Westinghouse Electric & Mfg. Co. February 24. Attendance 74.

Starting Characteristics of Synchronous Motors, by H. R. Sills, Canadian General Electric Co. March 9. Attendance 46.

Vancouver

Impressions of a Visit to Europe, by F. J. Bartholomew, Electrical Engineer. April 3. Attendance 34.

Washington, D. C.

Interconnection of Power Systems, by P. H. Chase, Philadelphia Electric Co. Motion picture, entitled "White Coal," was shown. A dinner preceded the meeting. March 13. Attendance 105.

Urban Transportation, by W. B. McClellan, Consulting Engineer. A dinner preceded the meeting. April 10. Attendance 36.

Worcester

Reminiscences of Steinmetz and Heaviside, by Dr. Ernest J. Berg, Union College. Joint meeting with A. S. M. E., A. S. C. E. and A. S. S. T. March 28. Attendance 100.

A. I. E. E. Student Activities

ENGINEERING EXPOSITION TO BE HELD AT LEWIS INSTITUTE

The Lewis Institute Branches of the A. I. E. E. and Western Society of Engineers are announcing their second annual Engineering Exposition to be held on May 16, 17, and 18. It is expected that this Exposition will surpass that of last year, both in size and in attendance.

No admission will be charged.

STUDENT MEETING HELD BY ITHACA SECTION

A meeting held by the Ithaca Section at Cornell University on April 13, 1928, was conducted entirely by the students under the auspices of the Electrical Engineering Association, and the following program was presented:

Alternator Oscillograph Studies, S. R. Knapp and J. R. Burnell.
Water Levels of Cayuga Lake, D. J. C. Werner

Polarization and Absorption in Dielectrics, E. J. Atkins, Jr.

Electric Locomotive Construction, D. W. Exner.

Refreshments were served after the completion of the program.

CONFERENCE ON STUDENT ACTIVITIES IN DISTRICT NO. 2

In connection with the Regional Meeting of the Middle Eastern District (No. 2), held at Baltimore, April 17-20, 1928, the second annual Conference on Student Activities of that District was held on the evening of the 19th. Twelve Counselors and about the same number of Branch Chairmen were present. Professor L. A. Doggett, Chairman of the District Committee on Student Activities and Counselor of the Pennsylvania State College Branch, presided.

The following program was presented:

The Institute and Student Branches, H. H. Henline, Assistant National Secretary, A. I. E. E.

Resumé of Student Branch Activities of the Middle Eastern District, No. 2, Morland King, Counselor, Lafayette College Branch.

What is My Branch Doing about Branch Paper Prizes? Open discussion.

Electrical Engineering Student Activities at Colleges Located in Large Cities, H. B. Dates, Counselor Case School of Applied Science Branch. W. B. Kouwenhoven, Johns Hopkins University. F. W. Lee, Johns Hopkins University.

Report of Outgoing Chairman of Committee on Student Activities, L. A. Doggett, Counselor, Pennsylvania State College Branch.

Open Discussion on the General Topic:

Wrinkles That Have Been Helpful in the Operation of Your Branch. Discussion by both Counselors and Student Branch Chairmen.

Professor King's report dealt principally with the Student Convention held at Lafayette College on March 19, 1928, and he said the students in charge of the arrangements had responded to their duties and opportunities in an admirable manner.

Means of encouraging students to submit more papers in competition for the national and regional prizes for Branch papers were discussed by a number of Counselors.

The majority of those present agreed that a Student Branch can be conducted very effectively in a large city, and that the presence of a Section does not in any way reduce the desirability of having a Branch, but, on the contrary, offers excellent possibilities of cooperation between the students and practicing engineers with benefits to both groups.

Professor Doggett reported briefly upon his plan for encouraging joint Branch meetings in the District and the two such meetings that were held during the present year. He exhibited curves showing the attendance at meetings of the Pennsylvania State College Branch and a number of other Branches.

Each Branch Chairman present gave a brief report concerning the activities of his Branch, and several expressed the hope that they would be able to use effectively some of the ideas received during the Conference.

At a meeting of the Counselors, Professor F. C. Caldwell, Counselor of the Ohio State University Branch, and Professor H. E. Dyche, Counselor of the University of Pittsburgh Branch, were elected Chairman and Vice-Chairman, respectively, of the District Committee on Student Activities for the year beginning August 1, 1928.

JOINT MEETING HELD BY CLEVELAND SECTION AND CASE SCHOOL OF APPLIED SCIENCE BRANCH

A very effective joint meeting was held on March 22, 1928, by the Cleveland Section and the Case School of Aplied Science Branch. The meeting was held in the Electrical Building of Case School, and all preparations were made by the students.

The program was as follows:

Address of Welcome, G. J. Currie, Chairman, Case School of Applied Science Branch.

Response, A. M. Lloyd, Chairman, Cleveland Section.

Activities of the Case School of Applied Science Branch, G. J. Currie, Chairman.

Activities of Student Branches, J. L. Beaver, Vice-President, District No. 2, A. I. E. E.

Application of Automatic Switching, R. W. Osterholm, Student.

Three-reel motion picture entitled, *Automatic Control of a Three-Wire Edison System.*

Problems in Converter Stations, R. G. Hornberger, Student.

A black-face comedy act was presented by M. S. Schonvizner and M. Hirshfield, Students.

Those present were then conducted through the laboratories by members of the Branch. Many special exhibits had been arranged for the meeting, and were very interesting to the visitors.

STUDENT ACTIVITIES CONFERENCE AND CONVENTION IN DISTRICT NO. 4

Following extensive preparations made by the Committee on Student Activities of the Southern District (No. 4) over a period of several months, a very effective two-day combined Conference on Student Activities and Convention was held at the Georgia School of Technology, Atlanta, on March 30 and 31, 1928, in cooperation with the Atlanta Section.

The program of the meeting was as follows:

Friday, March 30, 1928

9:00 A. M.

Counselors' Technical Session

Professor E. S. Hannaford, Chairman Committee on Student Activities, District No. 4, presiding.

Invocation.

Address of Welcome for A. I. E. E., C. O. Bickelhaupt, Vice-President District No. 4.

Address of Welcome for Georgia School of Technology, Dr. M. L. Brittain, President.

Research, Professor W. S. Rodman, Chairman Southern Virginia Section, and Counselor University of Virginia Branch.

The Relation Between Parallel Resonance and Anti-Resonance, Professor Walter J. Seeley, Counselor Duke University Branch.

1:00 P. M.

Student Technical Session

Professor E. S. Hannaford presiding.

Each student introduced by a professor from his school.

Modern Methods of Reproducing Sound, A. A. Berger, Georgia School of Technology.

The Performance of Various Solutions as Electrolytes in Electrolytic Rectification, E. R. Hauser, Alabama Polytechnic Institute.

Intermission—Music.

Automatic Telephony. R. E. Kepler, Chairman Washington and Lee University Branch.

The New Course in Electrical Engineering at Duke University, O. T. Colclough, Chairman Duke University Branch.

Application of Photoelectric Cells to Timing with Standard Clock, H. M. Roth, University of Virginia. (Presented by H. D. Forsyth, Chairman University of Virginia Branch).

After the adjournment of the afternoon session, the delegates were guests of the Georgia School of Technology Branch at a very interesting baseball game between that school and Oglethorpe University.

6:30 P. M.

Dinner with Atlanta Section

8:00 P. M.

Joint Meeting with Atlanta Section

D. H. Woodward, Secretary, Atlanta Section presiding.

A Solution of Power Factor Correction, B. T. McCormick Wagner Electric Corporation, St. Louis.

Saturday, March 31, 1928

9:00 A. M.

Conference on Student Activities

Professor E. S. Hannaford presiding.

Student Activities, H. H. Henline, Assistant National Secretary, A. I. E. E.

Student Branch Conventions, Professor W. J. Seeley, Counselor Duke University Branch.

Intermission—Music.

Student Branch Activities, W. J. Holman, Georgia School of Technology.

Student Branches and the Institute, Professor W. S. Rodman, Counselor University of Virginia Branch.

General Discussion.

1:30 P. M.

Inspection Trips

(a) Georgia Power Co. Noiseless Automatic Substation (Spring St.) and the Boulevard Substation.

(b) Telephoto Apparatus Inspection and Demonstration.

Several speakers emphasized the facts that the most important function of the Student Branches is the development of latent abilities of the students and this is accomplished most effectively by their active participation in the programs.

Among the recommendations made at the Conference on Saturday morning were those to the effects that good addresses at Regional Meetings be broadcast by radio and the Branches be notified in time to listen, and District officers invite each Branch in their District to send a delegate to Regional Meetings at the expense of the Branch.

It was decided that the next Conference on Student Activities in the District will be held at the time of the Regional Meeting in Atlanta, October 29-31, 1928, and that the Counselor of the Georgia School of Technology shall be Chairman of the District Committee on Student Activities. The Chairman was empowered to appoint such sub-committees as may be desirable, and to make arrangements for prizes for the best student papers presented at the next meeting.

Professor E. S. Hannaford was elected Counselor Delegate to represent the Committee on Student Activities of District No. 4 at the Summer Convention, to be held in Denver, June 25-29.

The entire meeting was interesting to all present. Ten Counselors and about the same number of Chairmen represented their Branches. The attendance at each of the technical sessions and the general conference was approximately 120.

THIRD ANNUAL STUDENT CONVENTION OF NEW YORK SECTION

BROOKLYN POLYTECHNIC WINS PRIZE FOR THIRD TIME

The third annual Student Convention of the New York Section was held on Thursday, April 19, 1928 in the Engineering Societies Building, 33 West 39th St., New York, N. Y.

Following the successful Student Convention of 1926 arrangements were made by the Section officers to place all responsibility for the success of future conventions in the hands of a Student Committee to be appointed each year. This plan proved eminently successful again this year, as all details for the 1928 meeting were handled by the Student Committee, subject only to the guidance of Branch counselors and Section officers. Eight colleges located in New York Section territory took part in the meeting. They were: Columbia University, Newark College of Engineering, Cooper Union, College of the City of New York, Rutgers University, Stevens Institute of Technology, New York University and Brooklyn Polytechnic Institute.

On Thursday morning there were student inspection trips to the Hellgate Power Station, Holland Tunnel Ventilating System, Bell Telephone Laboratories and the Roxy Theatre.

The afternoon session, held in the Engineering Societies Building, was devoted to the presentation of seven papers by representatives of seven colleges in competition for a prize of $25.00 in gold offered by the New York Section. Edward S. Bush, of the Newark College of Engineering, Chairman of the Student Committee, presided. L. W. W. Morrow, chairman of the New York Section made a short address. The balance of the afternoon was taken up by the presentation of the competing papers, as follows: *The Measurement of Composite Track Currents*, Barton Kreuzer, Brooklyn Polytechnic Institute; *The Gas-Electric Bus* (illustrated), A. H. Rapport, College of the City New York; *Rectifiers and Rectifier Tubes*, Donald Castle, Stevens Institute of Technology; *Preferred Home Lighting*, John P. Radcliff, Columbia; *The Shield Grid Tube*, J. F. Torpie, New York University; *The Watthour Meter*, (illustrated), Robert E. Mayer, Newark College of Engineering; *A-C. Networks*, Charles H. Coles, Cooper Union.

Members of the Committee of Award were unanimous in their decision giving the prize to Barton Kreuzer of the Brooklyn Polytechnic Institute with honorable mention to Robert E. Mayer of the Newark College of Engineering. The award to Mr. Kreuzer makes the Brooklyn institution a winner three years in succession. Attendance at the afternoon session was approximately 375.

At 6 p. m. a dinner for the students was given at the Fraternity Club, with about 175 in attendance. An after-dinner address on "The Young Engineer in Industry" was given by F. W.Willard, Personnel Director of the Western Electric Company. The Convention ended with the regular monthly N. Y. Section meetng with the students participating. That meeting is outlined elsewhere in this issue.

BRANCH MEETINGS

Municipal University of Akron

The Electric Locomotive and Its Control, by Mr. Webb, General Electric Co. A dinner preceded the meeting. March 8. Attendance 43.

Alabama Polytechnic Institute

The 132-Kv. Cable, by Mr. Lee, General Electric Co. Brief talks were also given by Mr. Stevens and Mr. McLaren, General Electric Co. March 15. Attendance 49.

University of Arkansas

Regional Meeting in St. Louis in March, by Professor W. B. Stelzner, Counselor, and W. H. Mann, Jr., Chairman. March 20. Attendance 14.

Measurements of Sound Pressure, by L. H. Barton, Director of Radio Station, KUOA, and Instructor of Radio at University of Arkansas. Nominating Committee appointed. April 3. Attendance 13.

Armour Institute of Technology

Diesel Engines and Their Relation to Industry, by F. Saldeth, Harneschfeger Corp. Joint meeting with A. S. M. E. and W. S. E. Branches. March 1. Attendance 55.

Bucknell University

Business meeting. Adoption of By-laws. March 21. Attendance 16.

California Institute of Technology

Annual student meeting of Los Angeles Section. (See Student Activities department in April issue of JOURNAL for more complete report.) March 6.

Motion pictures on Weston Instruments were shown. March 28. Attendance 14.

University of California

Initiation Banquet. Remarks on Engineering, by G. R. Henninger, Associate Editor, "Electrical West;" "The Responsibilities of the Engineer," by W. L. Winter, Chairman, San Francisco Section; "Travel Memoirs," by Robert Sibley, Executive Manager, California Alumni Association. L. D. Payne, student, spoke in behalf of the incoming men. Music and entertainment by students. March 1. Attendance 97.

The Recent Hydroelectric Power Developments on the Pacific Coast, by W. M. Moody, Pelton Water Wheel Co. Business session. Refreshments served. March 28. Attendance 48.

Inspection of the Vaca-Dixon Substation of the Pacific Gas and Electric Company. March 30. Attendance 17.

Carnegie Institute of Technology

Film, entitled "Big Deeds," was shown. Smokes, refreshments, and entertainment. March 7. Attendance 100.

Inspection trip to the Carnegie Steel Company at Homestead, Pa. March 3. Attendance 45.

Case School of Applied Science

Joint meeting with Cleveland Section in Electrical Building at Case School of Applied Science. (See more complete report elsewhere in this department.) March 22.

Catholic University of America

Engineering Reports in Connection with Financing Public Utilities, by M. J. Idail, Weller Construction Co. Refreshments served. March 12. Attendance 25.

Clemson Agricultural College

Recent Developments in Steam Turbines, by L. Anderson;

Recent Developments in Electric Railways, by L. S. Jackson;

Television, by G. W. Sackman, and

Current Events, by C. S. Lewis. March 1. Attendance 19.

Colorado State Agricultural College

Unit-Type Pulverizers Used in the Kalamazoo Plant, by Buell Clatworthy, student, and

Engineering Achievements in the Application of Electricity to Industry, by George Ball, student. February 27. Attendance 10.

Photoelectric Theory and Its Application to Industry, by Prof. H. G. Jordan, Counselor. March 12. Attendance 15.

University of Colorado

Transmission-Line Insulation, by G. L. Wilder, District Manager, Locke Insulator Co., Salt Lake City. Three-reel film on manufacture of insulators and a two-reel film on manufacture of large transformers were shown. February 29. Attendance 36.

Brief talks by E. C. Means, F. H. Heizberger, W. S. Trudgian, M. G. Graff and G. R. Ficke, Westinghouse Electric & Mfg. Co., on the Company and its products. Two-reel film "An Electrified Travelogue" was shown. March 7. Attendance 76.

All about Aviation, by J. Don Alexander, Alexander Aircraft Co., Denver. Five-reel film "Electrical Measuring Instruments" was shown. March 28. Attendance 150.

University of Denver

Business Meeting. March 6. Attendance 12.

General discussion of participation of the Branch in the program of the annual College Night of Denver Section, May 11. March 30. Attendance 15.

Duke University

Manufacture of Electrical Instruments, by A. F. Corby, Weston Electrical Instrument Corp. Illustrated with motion pictures. March 23. Attendance 27.

University of Florida

Transmission of Photographs by Wire, by W. H. Johnson, Chairman, and

Student Branch Conference held in Atlanta, Ga., March 30-31, by Professor Joseph Weil, Counselor. April 2. Attendance 25.

Georgia School of Technology

Elevators, Old and New, by W. T. Gage, Supt. of the Sales and Engineering Department of the Atlanta Branch, Otis Elevator Co. Slides. Student Branch, A. S. M. E., invited to attend. March 6. Attendance 94.

University of Idaho

Electrolytic Zinc, by William Reeves, student. Dinner was served. March 7. Attendance 25.

University of Kansas

L. H. Means, General Electric Co., spoke on the scope of research work carried on by his company. Moving picture "Speeding Up Our Deep Sea Cables" was shown. R. M. Alspaugh, Chairman gave a report on Regional Meeting of the South West District. March 14. Attendance 78.

Annual Banquet. O. M. Bundy acted as toast master. Talks were given by R. D. Woodson, W. E. Welch, Wm. M. Savage and R. S. Krehbiel. March 29. Attendance 186.

Louisiana State University

Salesmanship and Its Application to the Electrical Field, by Mr. Gay, Baton Rouge Electric Co. Motion picture, entitled "Revelations by X-Rays," was shown. March 2. Attendance 28.

Lehigh University

The Conowingo Hydroelectric Project and Its Interconnection, by N. E. Funk, Chief Engineer and General Manager, Philadelphia Electric Co.

Page Printing Telegraph Apparatus, by L. K. Sowers, student. Refreshments served. March 30. Attendance 110.

Lewis Institute

The Romance of Permalloy, by J. W. Andrews, Western Electric Co. April 5. Attendance 90.

University of Maine

Automatic Substations, by R. F. Scott and C. M. Flint, students. Films on automatic substations and oil-circuit breakers were shown. April 4. Attendance 15.

Massachusetts Institute of Technology

Principles of Electrical Measurements, by A. F. Corby, Weston Electrical Instrument Corp. Illustrated with film. March 9. Attendance 40.

Three reels of motion picture on the manufacture of porcelain and porcelain insulators were shown. March 21.

Inspection trip to Edison Lamp Works of the General Electric Company. March 22. Attendance 8.

Michigan State College

Business Meeting. March 12. Attendance 17.

University of Michigan

An American Engineer's Impressions of European Electrical Manufacture, by A. M. MacCutcheon, Engineering Vice-President, Reliance Electric & Engg. Co. March 14. Attendance 28.

Milwaukee School of Engineering

Atoms as Wonderworkers, by Dr. Henry Hubbard, Assistant to the Director of Bureau of Standards. Illustrated by models. March 22. Attendance 400.

Underground Power Distribution, by R. L. Dodd. April 6. Attendance 200.

University of Minnesota

Dinner and inspection trip at Riverside Station of Northern States Power Company. February 23. Attendance 101.

Mississippi A. & M. College

Electrically Driven Battleships, by E. S. Lee, General Engineering Laboratory, General Electric Co. March 22. Attendance 91.

University of Missouri

Four-reel educational film on electrical instruments was shown. March 29. Attendance 87.

Montana State College

Electron Theory, by Dr. Wendt, Head, Chemistry Dept., Pennsylvania State College. March 1. Attendance 150.

Electrons in Everyday Life, by H. T. Plumb, District Engr., General Electric Co., Salt Lake City, Utah. March 8. Attendance 98.

University of Nebraska

The Development of the New Type of Non-Electric Phonograph, by Dr. M. B. Long, (alumnus), Bell Telephone Laboratories, Inc., and

The Need of Industry for Engineers and What Industry Asks of Engineers, by S. Bracken, (alumnus), Technical Supt. of Western Electric Plant at Hawthorne. February 28. Attendance 53.

Summer Employment with the Westinghouse Electric & Manufacturing Company, by Ross Kilgore, student, and

Capacity Unbalance Tests on Chicago-New York Cable, by Kenneth Stiles, student. March 22. Attendance 35.

Newark College of Engineering

Illumination at Natural Bridge, Virginia, by W. A. Oglesby, Westinghouse Lamp Co. March 19. Attendance 25.

College of the City of New York

Business Meeting. Motion picture, entitled "Portable Electricity," was shown. March 8. Attendance 33.

Business Meeting. One-reel motion picture, entitled "Automatic Railway Substation," shown. March 29. Attendance 36.

Inspection trip to Hell Gate Power Plant. April 3. Atten dance 34.

Inspection trip to Otis Elevator Works at Yonkers. April 10. Attendance 17.

New York University

Studies in Illumination: Light and Industry, by R. J. Fluskey, '28, Secretary, and

A-c. Distribution in the Bronx, by Sheldon Trent, '28. March 22. Attendance 31.

University of North Carolina

Joint business meeting of A.I.E.E. Branch and A.S.C.E. Chapter. Dues of A.I.E.E. Branch were increased from $.50 to $1.00 per quarter. March 8. Attendance 28.

Developments of the Carolina Power and Light Company, by R. P. Crippen, Test Engr. Films. March 29. Attendance 25.

University of North Dakota

Engineering Opportunities in North Dakota, by Arnold Niehus, student, and

Report on District Conference on Student Activities at Lincoln on March 2 and 3, 1928, by Alfred Botten, Chairman. March 15. Attendance 19.

Motion pictures on modern telephone developments, radio telephony and television were shown. Discussion of plans for Engineers Day. March 29. Attendance 24.

Northeastern University

History of the Transatlantic Cable, by A. J. Mundt, Engg. Dept., Western Union Telegraph Co. March 20. Attendance 91.

Inspection trip to Hy-Grade Lamp Works, Salem, Mass. March 25.

University of Notre Dame

Indiana and Michigan Electric Company Substation Near South Bend, by Mr. Thoman, '28, and

Life and Works of Dr. Steinmetz, by Frank Gagliardi, '28. Refreshments served. March 19. Attendance 58.

Ohio State University

Power by Radio, by Dr. Phillip Thomas, Research Engineer, Westinghouse Electric & Mfg. Co. Joint meeting with Columbus Section, held at the University. Inspection trip to WEAO, the University broadcasting station. January 6. Attendance 200.

Development of Dynamo Machinery in Columbus, by Prof. W. A. Knight, Dept. of Industrial Engg. Dinner meeting. February 7. Attendance 45.

Social, Mental and Physical Balance in a Man, by C. S. Coler, Manager, Educational Dept., Westinghouse Electric & Mfg. Co. Brief remarks by a number of other Westinghouse men. February 23. Attendance 75.

Workers and Planners, by Prof. John Younger, Head of the Dept. of Industrial Engg. The following officers were elected: Senior Chairman, Robert G. Spry; Senior Vice-Chairman, E. R. Robinson; Junior Vice-Chairman, William M. Webster, Secretary-Treasurer, Graydon W. Trout. March 8. Attendance 45.

Appliction of Magnetic-Field Studies to Electrical Engineering, by E. E. Johnson, General Electric Co. March 15. Attendance 58.

University of Pennsylvania

Discussion of proposed trip to Conowingo. The following officers were elected: President, A. L. Pugh; Vice-President, B. F. Moore, Jr. February 20. Attendance 45.

University of Pittsburgh

Personal Experiences in the Engineering Field, by E. A. Casey, Engg. Dept., Union Switch and Signal Co. March 2. Attendance 39.

Personal Experiences in the Engineering Field, by F. R. Garman, Engg. Dept., Bell Telephone Co. of Pa. March 9. Attendance 39.

The Advantages of Working with a Small Concern, by H. A. Reitmeyer, student. March 16. Attendance 40.

Can One-Man Street Cars Render Safe and Adequate Service, by H. W. Wamhoff, student. March 23. Attendance 42.

South America, by R. Vecino, student. Slides.

C. O. Relays, by H. R. Jones, student. March 30. Attendance 40.

Purdue University

Lightning and Its Effects, by K. B. McEachron, General Electric Co. Meeting held in conjunction with the Indianapolis-Lafayette Section during the Meterman's Convention at the University. March 6. Attendance 300.

Rensselaer Polytechnic Institute

Operation of the High-Tension Systems Interconnecting the Large Steam and Hydroelectric Plants of New England, New York, New Jersey, Pennsylvania, and Canada, by C. W. Mayott, '11, Manager, Connecticut Valley Power Exchange. Slides. March 13. Attendance 120.

Rutgers University

Bimetallic Disk Thermostat, by Mr. Sherbo, '29;

Electricity in Color Matching, by Mr. Cost, '29, and

Vibration Absorbers for Large Single-Phase Machines, by Mr. Kieb, '28. March 12. Attendance 12.

University of South Dakota

Army Engineers and the Signal Corps, by Capt. Frank Ward. Plans made for Junior and Senior electrical engineering students to attend the meeting of the Nebraska Section at Omaha on April 26. March 21. Attendance 18.

Mercury Arc Rectifiers, by Stanley Boegler, student. April 4. Attendance 12.

Stanford University

Engineering smoker. Shirley Baker spoke on the business side of engineering. Entertainment, refreshments, and smokes were provided. February 29. Attendance 75.

Motion picture, entitled "Conowingo," was shown. March 9. Attendance 31.

A. & M. College of Texas

Dance. March 23. Attendance 105.

Development and Manufacture of Transformers, by E. J. Temple, General Electric Co. Slides. Two films on transformer manufacture and submarine cables were shown. March 30. Attendance 98.

Fundamental Units of Measurement in Electrical Engineering, by W. A. Knapp, '28, student. April 6. Attendance 36.

University of Texas

Power Transmission—Its History and Development, by O. S. Hockiday, Texas Power and Light Co. Slides. March 22. Attendance 33.

Transformers and High-Voltage Transmission, by E. J. Temple, General Electric Co. Slides. March 29. Attendance 28.

University of Utah

Motion picture, entitled "The Fabrication of Copper," was shown. Joint meeting with University of Utah Engineering Society. March 2. Attendance 60.

Business in America Is Good; Why Change it?, by D. C. Green, Vice-President and General Manager, Utah Power and Light Co. Joint meeting with University of Utah Engineering Society. March 9. Attendance 125.

The Fynn-Weichsel Motor as a Generaor of Electric Power, by O. K. Stigers, student. Dr. H. E. Mendenhall gave a short talk on the purposes and benefits of belonging to the A. I. E. E. March 13. Attendance 17.

Virginia Military Institute

Laboratory Improvements, by W. E. Englehard;

D-C. Machinery Used in Diesel-Electric Ship Propulsion, by L. Gwathmey;

Super Power and Its Aid to Progress, by C. N. Ballinger;

Locomotive Railroad Tests, by W. T. Wagner, and

The Effect of Lightning on Transmission Lines, by W. E. Black. March 24. Attendance 42.

Virginia Polytechnic Institute

Electrostatics, Electromagnetics, and Electrical Measurements, by A. F. Corby, Weston Electrical Instrument Corp. Motion pictures. March 29. Attendance 197.

University of Virginia

Modern Uses of the Photoelectric Cell, with Its Application to a Timing Mechanism, by Mr. Roth, Physics Dept. Motion picture, entitled "Voices Across the Sea," was shown by Mr. Cover, A. T. & T. Co., who described the opportunities for graduates in that company. February 22. Attendance 28.

State College of Washington

Motion pictures, entitled respectively, "The Electrical Giant" and "Big Deeds," were shown. February 23. Attendance 168.

A-C. Networks, by Ronald Niles. Discussion of papers for future meetings and plans for an Electrical Show. February 29. Attendance 29.

Washington University

Motion picture on the theory and manufacture of storage batteries was shown. March 2. Attendance 26.

Motion picture on the theory and manufacture of Weston instruments was shown. March 5. Attendance 30.

Business meeting. Committees were appointed to prepare for an Electrical Engineers' Smoker. April 5. Attendance 21.

University of Washington

Business meeting. March 9. Attendance 18.

Interconnection of Electric Service Systems, by E. Stuermer, student. April 5. Attendance 14.

West Virginia University

Sounds that Burn, by J. K. Gwinn; *Manufacture of Friction Tape*, by Ivan Vannoy; *Raising of Submarine S-4*, by F. M. Farry; *Telephone Toll Plant in the Chicago Region*, by W. S. Bosely; *Wire Glass*, by L. S. Davis; *Electrical Industry in Japan*, by H. V. DeJournett; *Electric Welding*, by W. T. Myers; *A. C. Operation of Radio*, by B. J. Paladino, and *Televox*, by H. H. Hunter. March 2. Attendance 28.

What Transportation Means to Progress of Cities, by S. J. Donley; *Granting of Patents*, by T. R. Cooper; *Transformers*, by M. C. Clark; *Electricity As Applied to the Petroleum Industry*, by C. C. Coulter; *Mercury Arc Rectifier*, by G. J. Burner; *Haphazard Economy*, by A. L. Lindlay, and *Yellow Pine Poles*, by R. N. Kirchner. March 9. Attendance 29.

Engineering Societies Library

The Library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES MARCH 1-31, 1928

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

Allgemeine Petrographie der "Olschiefer" und Ihrer Verwandten.

By Robert Potonié. Berlin, Gebrüder Borntraeger, 1928. 173 pp., illus., 10 by 7 in., paper. 12.-mk.

This treatise is in a sense an extension of the discussion of sapropel clay in the author's earlier work on the petrography of coal. In the present work he turns his attention to the oil shales and other rocks which contain bitumen, usually in solid form.

Beitrage Zur Geschiechte der Technik und Industrie; Jahrbuch des Vereines Deutscher Ingenieure. v. 17, 1927. Edited by Conrad Matschoss. Berlin, V. D. I. Verlag, 1927. 180 pp., illus., 12 by 9 in., cloth, 16.-r. m.

In order to make this yearbook less expensive its form and type have been changed to those used for other publications of the Society of German Engineers. The result is less pleasing to the eye, but the contents maintain the high level of previous years, and the set is indispensable to any student of engineering history.

The historical essays include articles on the cylinder printing press, spectacles, high-frequency engineering, insulators for aerial conductors, spinning and weaving, cylinder boring mills, and early railroad accidents. A biography of Volta is included, and a Venetian patent to Galileo is reproduced. A fully illustrated article on the engineering memorials of Germany contains many interesting examples of early work. A review of the year and a bibliography conclude the book.

Eiserne Balkenbrucken.

By Joseph Melan. Ber. u. Lpz., Walter de Gruyter & Co., 1928. 106 pp., illus., 6 by 4 in., lines. 1,50 r. m.

A brief text covering the essentials of the design and construction of steel bridges.

Electric Rectifiers and Valves.

By A. Güntherschulze; trans. & rev. by Norman A. De Bruyne N. Y., John Wiley & Sons, 1928. 212 pp., illus., diagrs., 9 by 6 in., cloth. $4.00.

A translation of Guenther-Schulze's "Elektrische Gleichrichter und Ventile," published in 1924, with various additions and emendations by the author and the translator. The book gives an account of the physical principles underlying valve action, and explains how these principles are applied in practice.

Elektrochemie, v. 4; Elektrolyse.

By Heinrich Dannel. Ber. u. Lpz., Walter de Gruyter & Co., 1928. 144 pp., illus., 6 by 4 in., linen. 1,50 r. m.

The concluding volume of Dr. Danneel's concise introduction to electrochemistry is devoted to the applications of electrical energy to the production of chemical reactions. The broad field is reviewed briefly, with emphasis upon the physico-chemical principles involved in the various processes.

Elektrotechnik, V. 1; Die Physikalischen Grundlagen.

By J. Herrmann. Ed. 5. Ber. u. Lpz., Walter de Gruyter & Co., 1928. 125 pp., illus., diagrs., 6 x 4 in., linen. 1,50-r. m.

This is the fifth edition of the first volume of Professor Herrmann's little textbook on electrical engineering, which aims to provide a brief, easily understood introduction to the subject. This volume explains the physical principles that underly the subject.

The text has been revised and enlarged.

Elements of Machine Design.

By James D. Hoffman and Lynn A. Scipio. Bost. & N. Y., Ginn & Co., 1928. (Engineering Series). 327 pp., illus., tables, 9 by 6 in., cloth. $3.80.

The authors have endeavored to present a course in which methods of attack upon problems are illustrated, by the use of typical examples of design, which will enable the student to get the greatest amount of information in little time. There are two main divisions in the book. The first lays down the fundamental principles, the second shows their application to design. Only simple mathematics is used.

English for Engineers.

By S. A. Harbarger. 2nd edition. N. Y., McGraw-Hill Book Co., 1928. 300 pp., 7 by 5 in., cloth. $2.00.

This book treats of English as a tool for transmitting thought and is planned to aid the engineer in acquiring skill in its use as a professional aid. It takes up first letters of applications, telegrams, orders, inquiries, and instructions, and the sales letters, which engineers must write; and then proceeds to more formal writing for publication. The advice given is sound and concise. There are numerous references for collateral reading, and the cultural value of general reading is not forgotten.

Erdstrome.

By Franz Ollendorff. Berlin, Julius Springer, 1928. 260 pp., diagrs., 9 by 6 in., bound. 20.-r. m.

The electric currents which forsake the predetermined paths in the earth and seek paths of their own, were until recently called "stray currents," and their effects were traced by designers and transmission engineers only in a very few cases. This state of affairs has changed with the erection of high-tension aerial lines: heavy, as well as weak, currents now pass through the earth; the hitherto unlimited space is smaller; utilization increases; calculated limitation must replace lavish waste of the "earth" material.

In this book our theoretical knowledge of the behavior of earth currents is summarized, and the formulas and mathematical methods are presented. The book is based on information assembled by the Siemens-Schuckert works and on some new investigations.

Grundlagen der Wechselstromtheorie.

By P. B. Arthur Linker. Berlin, Georg Stilke, 1928. 245 pp., 9 by 6 in., paper. Price not quoted.

A mathematical treatise on the theory of alternating currents. The author has endeavored to present the fundamentals of the subject and to give as elementary as possible treatment to the most difficult subjects, in order to make them available to wider circles. Especial attention is given to new concepts and to high-frequency engineering.

Highway Materials.

By Edward E. Bauer. N. Y., McGraw-Hill Book Co., 1928. 353 pp., illus., diagrs., tables, 9 by 6 in., cloth. $3.50.

While intended primarily to give students of highway engineering a general knowledge of the qualities of materials wanted for various kinds of pavements, this book will also be useful to engineers when writing specifications or inspecting materials or construction.

The first of its four parts gives a brief account of the production of each material, a general discussion of the purpose and value of each test applied to it, and the A. S. T. M. Specifications for it. In part two the qualities of material desired for each type of pavement are discussed and typical specifications are given. Part three, on sampling, gives the A. S. T. M. standard methods. Part four gives detailed instructions for making the various tests.

"Hutte," des Ingenieurs Taschenbuch, v. 3. 25th edition.

By Akademischen Verein Hütte, E. V. in Berlin. Berlin, Wilhelm Ernst & Sohn, 1928. 1203 pp., illus., diagrs., tables, 8 by 5 in., cloth. 18,60 r. m.

The third volume of the "Jubilee" edition of Huette has been thoroughly revised throughout and considerably enlarged. It is devoted to structural and railroad engineering, including the statics of structures, foundations, tunneling, high buildings, heating and ventilation, mill buildings, garages, contractors' equipment, hydraulic engineering, dams, roads, city planning, water and sewage works, railroads and bridges. Among the new subjects discussed are garage construction, new methods of street paving, athletic fields and stadiums, bath houses, and railroad safety equipment.

"Hutte," des Ingenieurs Taschenbuch, v. 4. 25th edition.

By Akademischen Verein Hütte, E. V. in Berlin. Berlin, Wilhelm Ernst & Sohn, 1927. 864 pp., illus., diagrs., tables, 8 by 5 in., cloth. 18.-r. m.

This volume covers a number of topics which have not been cared for in previous editions of Huette. It is intended to supply the mechanical engineer with the information of value to him on the mechanical technology of raw materials and articles of commerce which he uses in constructing and operating machinery. Processes of manufacture, properties, standards of quality, usual commercial varieties and efficiencies are given for materials and machines.

Among the topics treated are naval and marine engineering, automotive engineering, mining and milling, agriculture, foods, forestry, tanning, paper and textiles, ceramics, gas, printing, cinematography, radio, and packing.

Illuminating Engineering.

By Francis E. Cady and Henry B. Dates. 2d edition. N. Y., John Wiley & Sons, 1928. 515 pp., illus., diagrs., tables, 9 by 6 in., cloth. $5.00.

A brief, yet comprehensive survey of the subject and of current practice, prepared from the courses of lectures delivered by various specialists to students at the Case School of Applied Science. The theoretical principles of the art of illumination are presented, the sources of light are described, and approved methods for lighting residences, streets, signs, are explained.

The chapters on sign and display lighting and on light projection have been rewritten for this edition, and other sections have been corrected and revised.

Kesselanlagen fur Grosskraftwerke.

By Friederich Münzinger. Berlin, V. D. I. Verlag, 1928. 176 pp., illus., diagrs., plates, 11 by 8 in., linen. 19.-r. m.

In the first two-thirds of this book Dr. Münzinger gives a detailed account of the boiler plant of the Klingenberg power plant of the Berlin municipal electric system, from the original project to the completed installation. The various preliminary plans are described critically and the various steps in building, such as the construction of the boilers and accessories, erection, etc., are narrated, with attention to points of interest. The text and the numerous illustrations give an unusual picture of the many problems involved in a large plant.

With this as an example, the author then takes up the claims made for modern methods of firing and modern high-pressure boilers, and points out the ways to be followed to fulfill them. Further possible economies are pointed out.

Mathematical Preparation for Physical Chemistry.

By Farrington Daniels. N. Y., McGraw-Hill Book Co., 1928. (International chemical series). 308 pp., 8 by 6 in., cloth. $3.00.

This textbook is prepared for a special course in mathematics given to beginners in physical chemistry who have not the time

for the standard courses in analytical geometry and the calculus. It aims to give sufficient mathematical preparation for a first course in physical chemistry, and for some advanced courses.

DIE MESSWANDLER, ihre Theorie und Praxis.

By I. Goldstein. Berlin, Julius Springer, 1928. 166 pp., illus., diagrs., tables, 9 x 6 in., paper. 12.-r. m.

The author, an engineer in the A-E-G transformer factory, has attempted to provide a text on the theory and design of instrument transformers which will be of use, not only to designers and makers, but also to those using these instruments in the plant or the laboratory. Attention is also given to their fields of usefulness.

MOTOR TRAFFIC MANAGEMENT.

By G. Lloyd Wilson. N. Y., D. Appleton & Co., 1928. (Transportation Series). 251 pp., charts, graphs, 9 by 6 in., cloth. $3.00.

The author has been engaged for three years, he states, in collecting data dealing with traffic problems of motor bus and truck operators and in attempting to apply to these problems the principles of traffic management which have been evolved through the application of economic fundamentals to railroad, express and steamship business. He here presents the results of his labors.

THE NEW REFORMATION FROM PHYSICAL TO SPIRITUAL REALITIES.

By Michael Pupin. N. Y., Charles Scribner's Sons, 1928. 273 pp., ports., 8 by 6 in., cloth. $2.50.

The essays in this book, originally prepared for popular lectures, are intended to give persons without elaborate scientific training an understanding of the close relationship between the several physical realities which science has disclosed during the last four hundred years. Dr. Pupin hopes that a better understanding of them will hasten recognition of the relationship between physical and spiritual realities and of the absence of any conflict between science and religion.

PHYSICS IN INDUSTRY; Lectures delivered before the Institute of Physics, v. 5. Relation of Physics to Aeronautical Science, by H. E. Wimperis, and Physics in Navigation, by F. E. Smith.

Oxford Univ. Press; Lond., Humphrey Milford, 1927. 54 pp., illus., 10 x 6 in., boards. 2s 6d. (Gift of Oxford Univ. Press, American Branch, N. Y.)

The two lectures printed in this volume deal respectively with the relationship of physics to aeronautical science and with physics in navigation. The lectures are popular in style. They are intended to illustrate the help extended by physicists to workers in those fields and to call attention to problems requiring cooperative investigation.

POWER'S PRACTICAL REFRIGERATION.

Comp. by L. H. Morrison. N. Y., McGraw-Hill Book Co., 1928. 259 pp., illus., tables, 9 by 6 in., cloth. $2.50.

A handbook of practical information upon the construction, maintenance and operation of refrigerating machinery. The Text is simply written and assumes no scientific knowledge. It is based on articles that have appeared in "Power."

PRINCIPLES OF METALLOGRAPHY.

By Robert S. Williams and Victor O. Homerberg. 2d edition. N. Y., McGraw-Hill Book Co., 1928. (International Chemical Series). 259 pp., illus., tables, 8 by 6 in., cloth. $3.00.

An introduction to the subject, prepared with the needs in view of students of general science or engineering who do not intend to specialize in it, but who will use it to some extent in their professional work. It is also adapted for use as an introduction to metallography.

This edition has been thoroughly revised. Most of the photomicrographs have been changed. A chapter on the macroscopic examination of metals has been added.

RADIO-ELEMENTS AS INDICATORS and other selected topics in inorganic chemistry.

By Fritz Paneth. (George Fisher Baker Non-resident lectureship in chemistry at Cornell University). N. Y., McGraw-Hill Book Co., 1928. 164 pp., port., diagrs., tables, 9 by 6 in., cloth. $2.50.

This book contains the lectures delivered by the author during 1926-7 at Cornell University.

Excluding an interesting introductory on ancient and modern alchemy, these lectures fall into three groups. The first, and longest, group discusses the applications of radioactive elements as indicators in analytical and colloid chemistry, electrochemistry, inorganic chemistry, physics and technology. Group two deals with the preparation and properties of the volatile hydrides, and group three discusses the natural system of the chemical elements.

SCHALTBILDER IM WARMEKRAFTBETRIEB.

By W. Stender. Berlin, V. D. I. Verlag, 1928. 27 pp., illus., 8 by 6 in., paper. 1,80 r. m.

This little book presents a carefully planned set of symbols for use in representing power-plant machinery diagrammatically. Upon the basis of a few primary symbols, a complete system has been logically planned, which cares for all power-plant machinery and combinations.

STATISCHE u. DYNAMISCHE UNTERSUCHUNG VON MUNDUNGS-DAMPFMENGENMESSERN.

By S. Kreutzer. (Forschungsarbeiten auf dem Gebeite des Ingenieurwesens, No. 297). Ber., V. D. I. Verlag, 1928. 34 pp., diagrs., tables, 12 by 8 in., paper. 4,50 r. m.

Reports the results of an unbiassed investigation of two well-known models of steam flow meters, in which the influence of their mechanical design upon their accuracy was determined and special attention was paid to their behavior when measuring rapidly alternating and pulsating currents. It was found that the usual forms of apparatus cannot measure pulsating currents satisfactorily. The investigations also clarified the influence exerted by the method used to transmit the difference in pressure to the indicating device.

On the basis of the information obtained, a new meter was built and tested which gives both the difference in pressure and also the amount of flow through the throttling device in a given time. It also proved reliable for metering pulsating currents.

The investigations are fundamental in character. The results can be applied to other models than those tested.

A TREATISE ON THE ANALYTICAL DYNAMICS OF PARTICLES AND RIGID BODIES.

By E. T. Whittaker. 3d edition. Cambridge, Eng., University Press, 1927. [N. Y., Macmillan Co.]. 456 pp., 10 by 7 in., cloth. $8.50.

A treatise intended mainly for the advanced mathematician. It collects into book form the outlines of a long series of researches scattered through many periodicals. Numerous examples for solution are given.

The first fourteen chapters of this edition correspond closely to those in the second. The last two chapters, on the general theory of orbits and integration by series, have been completely rewritten.

UNTERSUCHUNGEN UBER DIE WASSERRUCKKUHLUNG IN KUNSTLICH BELUFTETEN KUHLWERKEN.

By Friederich Wolff. Mün. u. Bor., A. Oldenbourg, 1928. 62 pp., diagrs., plates in pocket, tables, 11 by 8 in., paper. 9.-r. m.

An experimental investigation of the laws governing the exchange of heat between water and air in forced-draft cooling towers. The research was carried out in the mechanical laboratory of the Charlottenburg Technical High School.

WORLD OF ATOMS; ten non-mathematical lectures.

By Arthur Haas. N. Y., D. Van Nostrand Co., 1928. 139 pp., illus., 9 by 6 in., cloth. $3.00.

The lectures printed in this volume were prepared for presentation to general audiences and are intended to give the lay public an account of the achievements of modern atomic physics. The author has avoided mathematics and has tried, with unusual success, to be brief, yet thorough, and easily understandable.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—31 West 39th St., New York, N. Y.,—W. V. Brown, Manager.
1216 Engineering Bldg., 205 W. Wacker Drive, Chicago, Ill., A. K. Krauser, Manager.
57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 31 WEST 39th Street, New York City,*** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by contributions made within thirty days after placement, on the basis of one and one-half per cent of the first year's salary: temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

MEN AVAILABLE

ELECTRICAL ENGINEER, 29, single, Swiss. Graduate Electrical Engineer of the Politechnical University, Zurich; European and American experience in design and layout of power plants and substations. Employed at present, desires new connection with consulting engineer. Speaks English, French and German. Excellent references. C-4254.

ELECTRICAL ENGINEER, 33. Licensed professional engineer, versatile, resourceful, 12 years' varied experience construction, operation and maintenance; considerable appraisal experience; has made physical inventory, conditioned, priced and edited engineering reports and appraisals on steam and hydro-electric stations, substations, transmission lines, distribution systems, gas, railway and industrial properties. Available immediately, salary commensurate. B-3455.

LICENSED PROFESSIONAL ELECTRICAL ENGINEER, 37, married; sixteen years' broad experience in electrical design, construction, and operation of power stations, substations; lighting and power for industrial buildings; office and experience in appraisal work; desires a new connection with an engineering organization or public utility. B-5393.

CHIEF ELECTRICIAN, married, 33. Fourteen years' practical experience with eight years technical business training in production problems and low cost maintenance. Can handle men and produce results. At present located with large electrical manufacturing company. Services available on reasonable notice. C-4288.

SALES ENGINEER, 26, married. One year Westinghouse Student course. Two years district office sales. Location, East or Middlewest. B-8699.

TECHNICAL GRADUATE, 42, married, desires permanent position as Mechanical, Electrical, Industrial Engineer or Executive in large company having several plants. Proven executive power development, operation, utilization; also application to manufacturing. Experience in textile, leather, paper manufacturing, design and fabrication of machinery. Seven years with General Electric Company. Now employed, desires change. A-1705.

SALES ENGINEER, 28, American. Graduate Electrical engineer with four years' experience in power plant and substation construction and two years' successful experience as security salesman. Would like to enter branch of the sales field where technical knowledge will be of value. Location preferred, East. B-7038.

ELECTRICAL ENGINEER, graduate, 34, married. Twelve years' experience industrial electrical engineering and designing, such as paper mills and refrigerating plants. Five years' experience in H. T. substation and power house design construction. Prefer field job. Now engaged, available on short notice. B-5251.

ELECTRICAL ENGINEER, 35, single. Degrees: B. A., Harvard; B. S. Electrical and Mechanical, Massachusetts Institute of Technology. Three years teaching, two years power station, one year radio research and development experience. Desires position in radio or electrical research laboratory, near Boston, Mass. C-4275.

SALES ENGINEER, graduate mechanical, radio and business college, 33, single; speaks several languages; extensively traveled Europe and Orient, Manchuria, India, Egypt; desires traveling or commercial or technical work, where his experience will be valuable. Location preferred, Far East or anywhere. C-3917.

TECHNICAL GRADUATE, 32, married. Varied experience including testing, electrical laboratory, substation operation. Five years meter and test engineer large industrial plant. Three years design, calibration and repair with manufacturer electrical instruments. Salary secondary to opportunity. Location, east of Mississippi river. C-4307.

ELECTRICAL ENGINEER, 30, married. B. S. '26; over two years' overhead distribution experience, estimating inspection and maintenance. Employed at present, large Eastern Utility. Desires connection with Public Utility preferably in California or Colorado. C-1629.

ELECTRICAL DESIGNER, 33, single. College graduate desires position as Electrical Designer; eight years' experience in power plant, indoor and outdoor substation design. Familiar with transmission line design, switchboard specifications and wiring diagrams. Location, preferably New York City. C-343.

GRADUATE ELECTRICAL ENGINEER desires position with Public Utility or industrial firm. Two years Westinghouse Test; three years assistant to Electrical Engineer of Industrial firm; five years assistant to Superintendent of by-product coke and water gas plant. B-8379.

EXECUTIVE OR ELECTRICAL ENGINEER, 40, married. 14 years' experience covering design, construction and maintenance distribution and transmission systems, substations and generating stations, equipment sales, purchases, statistics and special reports. Desires connection with Pbulic Utility or manufacturing concern. Southern or Central states preferred. B-9480.

ELECTRICAL AND MECHANICAL ENGINEER, 34, married. Technical University graduate. Five years' experience in design and construction of power plants and substations. Two years responsible position with electrical railway. Three years Public Utility. Practical type of man. Speaks and writes French and German fluently; working knowledge Spanish. Ability to handle men. Employed at present, available on reasonable notice. C-4046.

FOREMAN (UTILITY), 30, married. Ten years general utility work, commercial, also foreman and general foreman, construction, operation and maintenance; lines and substations. Has managed large substation district with little supervision. Good relations with employees and public. Location preferred, East. C-4110.

ELECTRICAL ENGINEER, 30, nine years experience; power house and substation design consulting experience: engineering, operating and distribution department, estimating, large utility company. Westinghouse Test Course. Will give return for $3600, to start, in congenial position. C-4257.

TECHNICAL GRADUATE, 24, single. Industrial Electrical Engineer. Two and a half years laboratory work; also same line construction experience. Desires position as sales engineer or installation engineer. Willing to travel. Location, immaterial. C-3818.

CONSTRUCTION MANAGER, graduate, fifteen years' public utility experience, open for connection as construction manager, chief engineer, operating executive for operating company. Now in charge three and a half million dollar high-tension transmission line and substation project, nearing completion. Can bring complete, experienced organization, financial, clerical and technical, to handle construction force of 500 men on power plant, transmission line, substation construction. A-2191.

ELECTRICAL ENGINEER, 25, single. Technical graduate, has had experience at practical, electrical work, Reliable, industrious, pleasing personality, willing to learn. Does not expect large salary, but desires work of a technical nature with good chances for advancement. C-4220.

SALES ENGINEER AND EXECUTIVE; 19 years' experience in engineering and sales work. Technical training with extensive acquaintanceship in Washington, Oregon, Idaho, Utah and Montana. Desires connection as representative above territory. Highly successful sales record in the Northwest. Good professional and social connections. Married. Excellent personality, appearance, health. Resident Seattle. C-4337-83-C-3 San Francisco.

ELECTRICAL ENGINEER, 34, single, degree E. E. Desires position with engineering concern

of public utility requiring executive ability. Ten years' experience covering engineering, design and valuation of power plants, substations, transmission and distribution lines. Location, East. B-389.

ELECTRICAL ENGINEER, 31, desires teaching position in electrical and related subjects, as assistant professor or instructor. Six years' experience as a teacher of electricity, physics and mathematics; four years as electrical designer and consultant; at present head of electrical department of large industrial school. C-2893.

ELECTRICAL DESIGNER, 28, single. Ten years' experience on design of power and substations; also distribution systems. Desires position with public utility. Location, immaterial. B-8628

ELECTRICAL ENGINEER, 34, married. M. S. and E. E. Eleven years' experience including teaching, operating department public utility, industrial research and design. Desires position having executive responsibilities with utility or industrial plant, where recognition is based on actual accomplishments. Location, anywhere, slight preference for West. B-7223.

POWER, EXECUTIVE OR OPERATING ENGINEER, 26, single. Four years' practical experience; construction and maintenance, D. C. power and lighting. One year substation operation; one years sales engineer; two years receiving engineer, high power radio receiving station Desires opportunity to work into above. Location, South or Southeast, preferred. C-2940.

ELECTRICAL AND MECHANICAL ENGINEER, 24, married. Graduate of 1925 with research experience on domestic and industrial oil-burners; technical and sales correspondence and specification work, 1½ years. Research experience on radio filters, voltage regulators, and power supplies 1½ years. Desires connection with large, stable firm in sales or research department. C-570.

ELECTRICAL ENGINEER, 36, married, University graduate. 14 years' experience designing and supervising installation, operation and maintenance of industrial, coal mining and power plant equipment; A. C. and D. C., manual, magnetic and automatic control. Desires permanent connection with opportunity for advancement. Location, immaterial. C-4322.

ELECTRICAL ENGINEER, Hindu, 26, single. Technical graduate, American State University. Broad, varied experience through graduate student-engineering course, big, American public utility. Two years operation, maintenance, construction, American steam, hydro power plants. Well acquainted American and Indian languages, customs, politics. Desires position in India with utility or manufacturing company. Indian and American references. C-4355.

INSTRUCTOR, 31, married, graduate Electrical Engineer. Ten years' active teaching experience, both lecture and laboratory, in vocational classes, high school, college. Especially qualified in communications, elementary theory, laboratory, both procedure and maintenance. Practical experience with manufacturing and utility companies. Desires college position. Now employed as instructor, public utility night school. C-1599.

ELECTRICAL ENGINEER, 34, single; experienced in testing and service departments of manufacturing company and design and construction of power houses, sub-stations, and switch yards; desires position in engineering department of public utility or holding company. Location preferred, East. B-4575.

ELECTRICAL ENGINEER, Filipino, from a well-known Middle West University, 25, specialized in railway engineering, desires experience with some electrical railway concern and to represent them in the future in his home country. Available at once. Location, New York or Philadelphia. C-3812.

ENGINEER, EXECUTIVE, MANAGER, graduate Electrical Engineer, married. 14 years' experience, including wide experience in accounting, design, sales, production, electrical procelain; manager of large plant for national corporation. Broad knowledge of engineering materials. Loyalty, initiative and record of assuming responsibility is unquestioned. Interested in business and management of electrical specialty. Can organize, manager operations efficiently and economically. C-3679.

ELECTRICAL SUPERINTENDENT. Construction, operation or maintenance, on utility, industrial or railroad. Graduate Electrical Engineer. Licensed in the State of New York. C-3467.

RESEARCH ENGINEER, 26, single, A. B., S. M. in E. E., cooperative course Massachusetts Institute of Technology; two years General Electric Company, standardizing laboratory and research laboratory; two years instructor in E. E. department Massachusetts Institute of Technology. Interested in communication work, particularly vacuum tues; familiar present practise, experienced high vacuum technique; good mathematical, theoretical training. Desires research or development position along these lines. C-4364.

ELECTRICAL ENGINEER, 26, graduate Electrical Engineer with 3½ years' well-balanced practical experience in various electrical manufacturing concerns desires position with a concern to develop into sales managership. Has initiative and ability. Excelleny references. Location, United States. C-2644.

CHIEF ELECTRICIAN, 28, single, desires position as chief electrician. Four years' experience in operation, maintenance and new construction work around industrial plant; also experienced on remote control work; some telephone work, parkway and lead cable, potheads. Satisfactory references as to character, ability and ability to get things done. Available immediately. Location, immaterial. C-2101.

ELECTRICAL ENGINEER, university graduate, 34, married. Ten years' experience, design, operation, maintenance, testing work of manufacturing and public utility companies in United States and Europe. Speaks and writes German and French. Desires position with consulting engineer, public utility company or manufacturer. Would also consider representing American manufacturer in Europe, Germany. B-9189.

GRADUATE ELECTRICAL AND MECHANICAL ENGINEER, 41, married with 15 years' experience in various phases of industrial operating and engineering work, particularly in power applications. Desires position as Plant Engineer or work of a similar nature. Available June 15. Will go anywhere. C-4373.

ASSISTANT EXECUTIVE of Department, with growing public utility or industrial company; graduate engineer, 32. Planning, estimating, budgeting, statistical, valuation, rate studies, production, operation, construction experience. B-9676.

TECHNICAL GRADUATE, 1922. Experienced in meter testing, electrical construction and maintenance. Location, immaterial. Available at once. B-7464.

SUPERINTENDENT OF PUBLIC UTILITY PROPERTY in city of 50,000 or less, or assistant superintendent of larger property. 15 years' experience in all phases of management and operation, commercial, engineering, construction, etc. Graduate Electrical Engineer. Middle-west or South preferred. Available on reasonable notice. C-4378

ELECTRICAL ENGINEER desires connection leading to executive or managerial duties. Technical graduate with successful experience in organizing nationwide engineering service. Training would qualify for service in lines other then electrical. B-122.

ELECTRICAL ENGINEER, 26, single, 1924 graduate. 4 years' experience in insulation research in a laboratory of a large concern. Desires position with a public utility in which there is opportunity for advancement and broad experience. Location preferred, United States. C-4386.

RADIO ENGINEER, B. S. and E. E. degrees. Experience includes radio production test in factory, radio development, research, carrier current telephone operation and maintenance, radio interference investigations, teaching of radio and electrical vocational classes, radio merchandising; public utility engineering. Would consider radio research, public utility work, sales engineering, along general lines of above experience. C-4347.

ELECTRICAL DRAFTSMAN, 24, single, desires position on power station or power distribution work. Experience in South America; speaks Spanish; best references. Location, New York City or South America. C-4382.

SENIOR IN ELECTRICAL ENGINEERING, of the graduating class of an Eastern College desires connection leading to executive or managerial duties. Experience: one-half year Crocker Wheeler motor test and assembly; one year General Electric Test. C-4393.

ELECTRICAL ENGINEER, 34, experienced in industrial maintenance, layout and construction. Eight years wire and cable test and manufacturing experience; some production and motor repair shop training; desires opportunity to prove ability. B-920.

EXECUTIVE with broad business and manufacturing experience desires connection. Has successfully held position of engineer, assistant to president, general manager in charge of manufacturing and commercial business, director of sales and engineering and executive vice-president. Widely traveled, good connections and best of references. C-4357.

PROFESSOR of Electrical Engineering or physics interested also in suitable industrial work. Has Ph. D. in physics and electrical engineering, about seven years' teaching experience and three years' industrial experience. C-3444.

ELECTRICAL SUPERINTENDENT, 39, married. Technical graduate steam and electrical engineering; 15 years' experience hydro- and steam power plants, construction, operation, maintenance, substations, distribution, electric railways, and industrial mill requirements. Location preferred, mild climate. C-3496.

POWER PLANT ECONOMY ENGINEER, A. S. M. E. and A. I. E. E., 26, single. Two years of general shop work, such as foundry, machine shop, forging and heat treatment, etc. Two years of general power plant experience, such as assembly and testing of steam and oil engines; turbines, their operation and maintenance; sub-station operation, etc. Location, California or anywhere. C-3978.

RECENT GRADUATE, S. B. in E. E., Massachusetts Institute of Technology, 1927; honor graduate, 22, single, desires a position either in engineering or teaching field. One year's teaching experience in large Northwestern University. Good habits, honest, conscientious, excellent references. Location, immaterial. Available June 15th. C-3550.

ELECTRICAL ENGINEER, 28, single, graduate, Scandinavian. Experience four years: 2½ in operation of sub- and power stations and industrial service abroad; 1½ years with electric railway company in United States. Knowledge of design and drafting. Thorough education. Location, immaterial C-3764.

ELECTRICAL ENGINEER, 28, married. Graduate Bliss Electrical School. Two years assistant stationary engineer; one year as stationary engineer, manufacturer; 3¼ years Westinghouse Test; 1½ years design large power transformers. Desires position with Public Utility with opportunity for expanding. Location, immaterial. C-3073.

MEMBERSHIP—Applications, Elections, Transfers, Etc.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting of April 4, 1928, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at one with the National Secretary.

To Grade of Member

BAUHAN, OSCAR, Engineer, Public Service Elec. & Gas Co., Newark, N. J.
BRODSKY, Designer, United Elec. Lt. & Pr. Co., New York, N. Y.
BUTTERWORTH, RUSSELL I., General Supt., Bristol Gas & Elec. Co., Bristol, Tenn.
CHARTIER, HAROLD S., Division Engineer, N. Y. Power & Light Corp., Gloversville, N. Y.
CLARK, WALTER JOHN, Engr. of Equipment and Maintenance, General Elec. Co., Pittsfield, Mass.
DOLPH, NORMAN L., Transmission Engineer, Stevens & Wood, Inc., New York, N. Y.
EDWARDS, PAUL G., Telephone Engineer, American Tel. & Tel. Co., New York, N. Y.
EVANS, JAMES M., Electrical Engineer, Board of Fire Underwriters, Los Angeles, Calif.
FAIRMAN, F. E., Switchboard Specialist, General Electric Co., Pittsburgh, Pa.
FALL, C. B., Sales Engineer and Owner, C. B. Fall Company, St. Louis, Mo.
FELDMANN, WALTER H., Director of Sales, Electrical Machinery Mfg. Co., Minneapolis, Minn.
FOLLINE, W. B., Switchboard Engr., General Elec. Co., Dallas, Texas.
FORD, FRANK R., Asst. Engr. of Electrical Design, Philadelphia Elec. Co., Philadelphia, Pa.
GILLIAM, MARION W., District Manager, West Virginia Engg. Co., Williamson, W. Va.
GILSON, WESLEY J., General Supt. of Pr. and Const., N. Y. Power & Light Corp., Schenectady, N. Y.
GOLDHAMMER, MAX H., Sales Engr., Industrial Dept., General Elec. Co., New York, N. Y.
GOODWIN, WALTER C., Section Engineer, Westinghouse E. & M. Co., E. Pittsburgh, Pa.
GRAF, FRANK G., General Engr., Westinghouse E. & M. Co., New York, N. Y.
HEARN, GEORGE K., Service Engr., Westinghouse E. & M. Co., New York, N. Y.
HONEGGER, ARNOLD, Asst. Director, Business Research Corp., Chicago, Ill.
HUDSON, WILLIS F., Director of Engg. Research, The Hoover Co., North Canton, Ohio.
INAGAKY, TADA Y., President, T. Y. Inagaky & Co., Tokyo, Japan.
JACOBI, EDWARD N., Chief Engineer, Briggs Stratton Corp., Milwaukee, Wis.
LeCLAIR, GIFFORD, Partner in firm of Densmore, LeClair & Robbins, Boston, Mass.
McFARLANE, MAYNARD L. D., Manager, Bartlane Dept., *N. Y. Daily News*, New York, N. Y.
METZNER, MAXWELL W., Asst. to Supervisor of Tests, General Elec. Co., Erie, Pa.
MOLLER, THURE B., Electrical Designer, Gibbs & Hill, New York, N. Y.
MYERS, ALEXANDER M., Elec. Engr., Standard Underground Cable Co., Pittsburgh, Pa.
NIMS, ALBERT A., Associate Prof. of Elec. Engg., College of Engineering, Newark, N. J.
OSTERLE, WILLIAM HENRY, Division Engineer, West Penn Power Co., Connellsville, Pa.
PATTON, RALPH C., President and Manager, Patton-MacGuyer Co., Providence, R. I.
RAH, JOSEPH, Chief Engineer, 7780 Dante Ave., Chicago, Ill.
REQUE, STYRK G., Chief Engineer, Penn. Pr. & Lt. Co., Allentown, Pa.
ROHRBACH, FRANKLIN L., Maintenance Engr., Washington Water Power Co., Spokane, Wash.
RYMER, DONALD H., Telephone Engineer, American Tel. & Tel. Co., New York, N. Y.
SCHUCH, LELAND S., Elec. Engr., Colorado Portland Cement Co., LaPorte, Colo.
SEELEY, WALTER J., Associate Prof. of Elec. Engr., Duke University, Durham, N. C.
SHARPE, CLARENCE B., District Operating Engr., Hydro Electric Pr. Comm. of Ontario, Toronto, Ont., Canada.
SNOOK, WARD H., Consulting Engr., 40 West Gay St., Columbus, Ohio.
SWIFT, HERBERT A., Chief Estimator, Toronto Hydro Electric System, Toronto, Ont., Canada.
TAYLOR, DONALD W., Asst. Elec. Engr., Public Service Production Co., Newark, N. J.
TERRY, FRANCIS M., Chief Asst. to Rate Engr., New York Edison Co., New York, N. Y.
THOMPSON, FRANCIS R., Railway Engr., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
TOWNSLEY, FREELAND P., General Supervisor of Equipment Practices, Western Elec. Co., Kearny, N. J.
VAN VEEN, JOHN, Chief Operator, Elec. Prod. Dept., Union Gas & Elec. Co., Cincinnati, Ohio.
WAHLBERG, NILS A., Section Engineer, Westinghouse E. & M. Co., Derry, Pa.
WALDINGER, HENRY, Elec. Engr., and Master Electrician, Press Publishing Co., New York, N. Y.
WARREN, WILLIAM H., Equipment Engineer for Spain, International Tel. & Tel. Corp., Madrid, Spain.
WIMMER, JOSEPH, Transmission Engineer, Pacific Tel. & Tel. Co., Spokane, Wash.
WINEGARTNER, CARL E., Elec. Engg. Dept., Cleveland Elec. Illum. Co., Cleveland, Ohio.
WINTERHALTER, THEODORE S., Asst. Engr., Public Service Prod. Co., Newark, N. J.
WOOTTOON, THOMAS W., Senior Designing Engr., Duquesne Light Co., Pittsburgh, Pa.
WRIGHT, GEORGE I., Engineer Electric Traction, Reading Co., Philadelphia, Pa.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before May 31, 1928.

Allen, R. W., Georgia School of Technology, Atlanta, Ga.
Almquist, C. T., Colorado Agricultural College, Fort Collins, Colo.
Appleton, F. W., (Member), New York Telephone Co., New York, N. Y.
Archer, E. G., Ontario Hydro-Electric Commission, Toronto, Ont., Can. (Applicant for re-election.)
Baker, T. S., Radio Corp. of America, Bolinas, Calif.
Balp, E., General Electric Co., Pittsfield, Mass.
Belinge, R. A., East Bay Cities Rate Dept., Oakland, Calif.
Bell, F. A., Jr., Mississippi Power & Light Co., Jackson, Miss.
Bird, B., Westinghouse Elec. & Mfg. Co., East Springfield, Mass.
Boothe, M. C., Western Electric Co., Chicago, Ill
Bourland, L. T., University of Illinois, Champaign, Ill.
Bowen, R. G., Bell Telephone Laboratories ,Inc., New York, N. Y.
Brand, C. R., Buffalo Electric Co., Buffalo, N. Y.
Brane, M. DeF., Atmospheric Nitrogen Co., Solvay, N. Y.
Buss, C. W., Public Service Co. of No. Illinois, Evanston, Ill.
Carpenter, E. M., Milestone Electric Light Works, Milestone, Sask., Can.
Clement, C. W., Hydro-Electric Plant, Bridgeport, Calif.
Cline, H. D., Mountain States Tel. & Tel. Co., Bozeman, Mont.
Coleman, J. F., Champion Fibre Co., Canton, N. C
Connell, A. C., Commonwealth Power Corp., Jackson, Mich.
Cowling, D. R. G., Canadian National Telegraphs, Toronto, Ont., Can.
Daugherty, J. E., Bear Valley Utility Co., Los Angeles, Calif.
Dennis, R. E., Columbia Engg. & Management Corp., Cincinnati, Ohio
Dietz, W. F., Westinghouse Elec. & Mfg. Co., Washington, D. C.
Dreischmeyer, E. S., San Joaquin Light & Power Corp., Fresno, Calif.
Eckert, C. C., National Lamp Works, G. E. Co., Nela Park, Cleveland, Ohio
Engelbrecht, H. K., Southern Sierras Power Co., Riverside, Calif.
Erskine, A. J., Milwaukee Electric Railway & Light Co., Milwaukee, Wis.
Faust, C. W. H., General Electric Co., Philadelphia, Pa.
Fox, R. C., Regina Dental Laboratory, Regina, Sask., Can.
Glenn, T. G., General Electric Co., Chicago, Ill.
Grossman, M. L., American Machine & Foundry Co., Brooklyn, N. Y.
Haggart, G. J., Canadian General Electric Co., Peterboro, Ont., Can.
Harvey, L. B., Porcelain Insulator Corp., Lima, N. Y.
Heard, R. P., 34 Harold Ave., San Francisco, Calif.
Hoffman, J. P., Jr., Bell Telephone Laboratories, Inc., New York, N. Y.
Howard, C. G., Fansteel Products Co., North Chicago, Ill.
Hu, Zai-Hsiang, New Jersey Bell Telephone Co., Newark, N. J.
Hyatt, W. R., Canadian General Electric Co., Toronto, Ont., Can.
Johnson, E. D., (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Jones, A. L., Fostoria Glass Co., Moundsville, W. Va.
Kelly, E. J., New York Light & Power Co., Glens Falls, N. Y.
Kern, B. B., Penn. Power & Light Co., Danville, Pa.
Kirkpatrick, P. W., Elec. Engr. with H. S. Sands, Denver, Colo.
Koerner, C. A., Delta-Star Electric Co., Chicago, Ill.
Krudop, H. F., General Electric Co., Fort Wayne, Ind.
Kushlan, M., (Member), Stone & Webster, Inc., Boston, Mass.
Laird, A. M., Scranton Electric Co., Scranton, Pa.
Ludwig, L. R., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

MacBurney, A. C., New York Power & Light Corp., Amsterdam, N. Y.
Marzulli, A. M., University of Cincinnati, Cincinnati, Ohio
Mathis, A. B., Atchison, Topeka & Santa Fe Railway Co., Los Angeles, Calif.
Maynard, H. M., (Member), Brooklyn Edison Co., Brooklyn, N. Y.
McAfee, H. E., (Member), Mountain States Tel. & Tel. Co., Denver, Colo.
McCloskey, D. J., Consulting Engineer, Salem, N. J.
McDonald, R., Weston Electrical Instrument Corp., Waverly Park, Newark, N. J.
McJilton, D., Electrical & Radio Equipment Mfg., Chicago, Ill.
McWhan, B., Bell Telephone Laboratories, Inc., New York, N. Y.
Miller, C. I., Industrial Brownhoist Corp., Cleveland, Ohio
Morris, R. M., (Member), Mountain States Tel. & Tel. Co., Denver, Colo.
Mulbacher, L. J., Western Electric Co., Chicago, Ill.
O'Clare, A. R., Cuba Mail S. S. Co., New York, N. Y.
Ogden, F. P., (Member), Mountain States Tel. & Tel. Co., Denver, Colo.
Peck, J. M., Porcelain Insulator Corp., Lima, N. Y.
Penzickes, C., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Perry, E. H., Worcester Electric Light Co., Worcester, Mass.
Perry, G. E., Johns Manville Corp., Manville, N. J.
Pethick, F. C., D. L. & W. R. R. Co., Scranton, Pa.
Philips, J. H., (Member), Oklahoma Gas & Electric Co., Oklahoma City, Okla.
Pickell, C. A., General Railway Signal Co., Rochester, N. Y.
Reid, F. H., (Member), Mountain States Tel. & Tel. Co., Denver, Colo.
Reid, R., (Member), Mountain States Tel. & Tel. Co., Denver, Colo.
Rextrew, W. C., General Electric Co., Philadelphia, Pa.
Rowdabaugh, S. C., Byllesby Engineering & Management Corp., Pittsburgh, Pa.
Ruckagauer, A. E., Electric Bond & Share Co., New York, N. Y.
Ruiz, A. R., Consulting Engineer, Havana, Cuba
Rutherfurd, G. R., So. California Telephone Co., Los Angeles, Calif.
(Applicant for re-election.)
Schoenfeld, L. W., Philadelphia Electric Co., Philadelphia, Pa.
Schultz, J. C., Omaha Council Bluffs St. Railway Co., Omaha, Nebr.
Schwarzler, C., Jr., Protective Fuse & Plug Corp., Passaic, N. J.
Seymour, N. F., Hydro-Electric Power Commission, Toronto, Ont., Can.
Smith, F. J., University of Minnesota, Minneapolis, Minn.
Smith, M. W., Tri-State Tel. & Tel. Co., St. Paul, Minn.
Stanley, G. W., Frazee Organ Co., Everett, Mass.
Switzer, R. H., Canadian General Electric Co., Toronto, Ont., Can.
Taylor, H. L., Department of Public Works, Vancouver, B. C.
(Applicant for re-election.)
Traub, L. A., Home Tel. & Tel. Co., Spokane, Wash.
Travers, J. E., Pratt Institute, Brooklyn, N. Y.
Weichel, P. F., Scranton Electric Co., Scranton, Pa.
Wiegand, F. J., Dept. of City Transit, City of Philadelphia, Philadelphia, Pa.
Young, H. E., Scranton Electric Co., Scranton, Pa.
Total 91.

Foreign

Andrews, R. C. P., Otago Electric Power Board, Dunedin, N. Z.
Bobrovsky, L. S., Svir Hydro-Electric Development, Svirstroi, Russia
Cave, P. W., Macintosh Cable Co., Ltd., Walton, Liverpool, Eng.
Chinoy, P. N., Empress Mills, Nagpore, C. P. India
Clark, J. G., Cathcart Municipality, Cathcart, So. Africa
Dalgleish, J. W., Metropolitan-Vickers Co., Ltd., Trafford Park, Manchester, Eng.
McVea, D. C., Public Works Dept., Sydney, N. S. W., Aust.
Ramasawmi, A. V., Bellary Municipal Electrical Works, Bellary, So. India
Ramos, G. deA., Sao Paulo Tramway, Light & Power Co., Ltd., Sao Paulo, Brazil, S. A.
White, S. H., Public Works Dept., Sydney, N. S. W., Aust.
Yates, L. H., Public Works Dept., Sydney, N. S. W., Aust.
Total 11.

STUDENTS ENROLLED

Arnhols, Arendt J., Cooper Union
Bagdon, Joseph A., Brown University
Berry, Wayne S., Worcester Polytechnic Inst.
Bishofberger, Carl J., University of Wisconsin
Brown, William H., North Carolina State College
Caruso, Carmine, Cooper Union
Christman, Francis J., University of Illinois
Curtis, Arthur E., Jr., McGill University
Davis, Edward W., University of Louisville
DeLanty, Loren J., Cooper Union
DeVoe, Frank K., Cooper Union
Di Fusco, F. J., Cooper Union
Edwards, Robert J., Northeastern University
Fethi, I. S., Cooper Union
Figiel, Walter J., Cooper Union
Fruhner, Ernest T., Cooper Union
Guillory, Ural, Louisiana State University
Hammit, Harry C., Virginia Polytechnic Institute
Harris, Herbert, Cooper Union
Heney, Frederick G. G., McGill University
Henschel, Wilfred, Cooper Union
Holdgrafer, Vincent H. J., Montana State College
Jenkins, Jett M., University of Florida
Lambdin, James H., Mississippi Agri. & Mech. College
Lanterman, W. F., Purdue University
Levinton, Harold L., Mass. Institute of Tech.
Lore, William E., University of Michigan
Lyle, Edwin A., Jr., Mississippi Agri. & Mech. College
Mellrud, Harold E., State College of Washington
Metcalf, G. F., Purdue University
Millis, Walter T., University of Pittsburgh
Nazor, Hugh M., University of Louisville
O'Hara, Eric, University of Cincinnati
Orovan, Herman E., Cooper Union
Perley, Ernest C., McGill University
Piche, Armand A., University of Vermont
Richardson, John M., McGill University
Robeson, James M., Union College
Rudiger, Carl E., Cooper Union
Rupert, Harold B., Purdue University
Salma, Emanuel A., Cooper Union
Schaub, Wallace R., Cooper Union
Shafer, Wilson E., Virginia Polytechnic Institute
Sumption, Henry C., Virginia Polytechnic Inst.
Tallman, F. H., Cooper Union
Tayek, Reuben J., Engg. School of Milwaukee
Thomas, Robert H., Jr., Virginia Polytechnic Inst.
Towne, Robert L., Worcester Polytechnic Inst.
Walsh, Thomas N., University of Texas
Warren, Charles T., Jr., Georgia School of Tech.
Winans, Roswell R., Newark College of Engg.
Wunsch, Benjamin A., University of Wisconsin
Yang, Jay Y., Swarthmore College
Zamora, Lorenzo, Engg. School of Milwaukee

Total 54.

OFFICERS A. I. E. E. 1927-1928

President

BANCROFT GHERARDI

Junior Past Presidents

C. C. CHESNEY
M. I. PUPIN

Vice-Presidents

H. M. HOBART
O. J. FERGUSON
B. G. JAMIESON
E. R. NORTHMORE
GEORGE L. KNIGHT
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Motor Generator Sets.—Bulletin 450, 12 pp. Describes a line of motor generator sets for various requirements. Price list is included. A few of the applications include battery charging, emergency lighting, welding, electroplating, and motion picture projection. Roth Brothers & Company, 1400 W. Adams Street, Chicago, Ill.

Potheads and Distribution Specialties.—Catalog 27, comprises bulletins on the complete G & W line of potheads, boxes, vault units, oil switches and distribution specialties. Installation instructions, photographs and other useful information are conveniently arranged. G & W Electric Specialty Company, 7780 Dante Avenue, Chicago, Ill.

Motor Starters.—Bulletin 112, 12 pp. Describes Thermaload starters, comprising standard Monitor magnet contactors mounted on panels with thermal relays and enclosed in steel cabinets arranged for conduit wiring. Positive protection to polyphase and single-phase motors, both while starting and running, is claimed for this starter. Monitor Controller Co., 55 Gay Street, Baltimore, Md.

Portable Compressors.—Bulletin, 140 pp., entitled "100 and 1 Ways to Save Money With Portable Compressors." This two-color book contains a great variety of comparative cost data, as well as three hundred interesting photographs. It shows the savings that can be effected by using portable air compressors and air-operated tools on construction and maintenance work. Ingersoll-Rand Company, 11 Broadway, New York.

Asbestos Insulated Wires and Cables.—Bulletin. Decribes an asbestos and varnished cambric insulated switchboard wire with a smooth outer cotton braid. This wire is one of several types described in the "Rockbestos Switchboard Wires and Cables" bulletin. Two other new bulletins are "Rockbestos A. V. C. Cables" (asbestos and varnished cambric). The most exhaustive of the three is the "Rockbestos Wires and Cables" bulletin which contains the standard specification for all Rockbestos insulated wires and cables as to the quality of the copper, the asbestos and the method of impregnating, testing and inspecting. Rockbestos Products Corporation, New Haven, Conn.

NOTES OF THE INDUSTRY

The Minerallac Electric Company announces that after the first of May all business will be transacted in its new office and factory building at 25 North Peoria Street, Chicago, Ill.

The Wagner Electric Corporation, St. Louis, Mo., announces the removal of its New York City branch sales office from 50 Church Street to suite 1110, 30 Church Street. The New York City service station remains at 321 West 54th Street.

The Rockbestos Products Corporation, New Haven, Conn., has appointed C. Dent Slaughter as its Pacific Coast representative, with offices at 314 Twelfth St., San Francisco; 324 N. San Pedro St., Los Angeles; 200 N. 13th St., Portland and 1108 Post St., Seattle.

General Electric Sales.—According to President Gerard Swope, the General Electric Company's sales billed for the first three months of 1928 amounted to $71,640,790.40, as compared with $72,474,474.03 for the corresponding period last year. Profit available for dividends on common stock for the first quarter of 1928 was $11,261,842.71 compared with $11,028,143.96 for the same three months last year.

New Matthews Fuswitch.—The W. N. Matthews Corporation, of St. Louis, manufacturers of Matthews Fuswitches, scrulix anchors, reels, slack pullers, etc., announces a new open type Fuswitch which has been designed for rural and farm lighting and railroad use to meet the demand for a dependable open type Fuswitch of high rupturing capacity to sell at a low price. This new Fuswitch is known as the 1317 Matthews Fuswitch with a rating of 100 amperes and 7500 volts. It is a vertical, open type switch especially designed for 6600 and 6900 volt service, and adaptable to 2300 and 4400 volt service. In addition to being well suited for rural and farm lighting, it is very adaptable to railroad use where a switch is needed with firm contacts of low resistance that guard against current losses and radio interference.

Personnel Changes in Hubbard & Company Organization.—Announcement has been made by C. L. Peirce, Jr., vice-president in charge of the electrical materials business of Hubbard & Company, Pittsburgh, manufacturers of Hubbard pole line hardware and Peirce construction specialties, of the following organization changes: Joseph V. Smith, formerly Pacific coast manager, has been made eastern manager in charge of the Pittsburgh plant and the territory served by it. W. R. Pounder continues as central manager in charge of the Chicago plant and the territory it serves. Norris C. Husted, formerly manager of the Niles plant, has been made Pacific coast manager in charge of the Emeryville, California, plant and the Pacific Coast territory. Wallace W. Glosser, formerly sales manager of the Verona Tool Works, has been made New York district sales manager with headquarters at 30 Church Street, New York, N. Y.; Thomas J. Farrell, formerly sales manager of the Universal Sales Company, has been made special representative in the New York district. Two large additions to the Pittsburgh plant are nearing completion and it is the intention during May to move the Niles operation to Pittsburgh.

Germany World's Largest Exporter of Electrical Products.—Germany has now become the world's foremost exporter of electrical equipment, outdistancing both the United States and Great Britain, a trade bulletin just issued by the Commerce Department reveals. Up until last year the electrical manufacturers of these three countries were running a neck and neck race for the leadership in the exporting field with the United States having a slight advantage. During 1927, however, the German industry forged to the front, total shipments to foreign markets reaching a value of $120,000,000 as compared with $102,000,000 for the United States and approximately $80,000,000 for Great Britain.

The basis of Germany's advance in electrical exporting, according to the bulletin, rests on the price factor. In the matter of such appliances as lighting fixtures, switches, etc., the German producers do not attempt to turn out a finished product such as is the practise in the United States and the material is as a rule much lighter. The larger items, such as turbines, generators and motors are of excellent manufacture, but because of much lower labor costs these can also be sold at prices under American quotations.

Germany's electrical products, the report discloses, are shipped to every part of the world, although its best customers are in Europe. The Netherlands is Germany's largest customer for electrical lines, followed by Great Britain, Russia, Argentina, Sweden and Italy. In 1927 shipments of German electrical items to the United States were valued at about $2,000,000, about 2 per cent of Germany's total exports.

The German electrical industry, according to the report, is apparently in a very prosperous condition. It is strongly entrenched in the foreign field and that its position there will be consolidated or, at least, that an effort will be made in that direction, is evidenced by the fact that there is a decided tendency to pool forces among German manufacturers.